Using Landscape Theory to
Analyze Mobile OS Platform Adoption by Mobile Device Manufacturers

by

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Abstract

Increasingly businesses are realizing the realities of the global economy, in which differentiation plays a big role in making a business profitable. In order to keep up with the accelerated pace of innovation, firms must move fast to capture opportunities and revenue. Rapid innovation cycles are possible today, only when firms take advantage of complementary assets of other firms and work collaboratively. This is true of the mobile phone industry as well.

This research aims to investigate the efficacy of landscape theory as a model with which to understand alliances formed between device manufacturers and operating system platform providers in the mobile ecosystem. The findings reveal that the model closely matches the actual maneuverings of these companies and provides a basis for further study of this industry using landscape theory constructs.

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This thesis was a long time in the making and its completion is a triumphant moment for me personally. This journey has taught me many research and analytical skills but most importantly it has reinforced how important proper guidance and support are to any achievement of this kind.

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1   Chapter: Introduction

Increasingly businesses are realizing the realities of the global economy, in which differentiation plays a big role in making a business profitable. In order to keep up with the accelerated pace of innovation, firms must move fast to capture opportunities and revenue. Rapid innovation cycles are possible today, only when firms take advantage of complementary assets of other firms and work collaboratively. Stopping to reinvent the wheel can result in firms having to play catch up later, or worse, becoming irrelevant altogether.

In this new interdependent and collaborative business world, Moore's (1993) seminal work on the structure of businesses as an ecosystem of dependent entities is becoming not only more relevant, but perhaps the only way to characterize and explain business interactions today.

Part of the central premise of an ecosystem is the emergence of a platform on top of which businesses can offer value-added products and services. This framework of organizing firms is seen across many industries, including the PC industry and the Internet. This type of organization is also emerging in the converging mobile ecosystem, where mobile operating system (OS) providers are poised to take the central role of platform providers, also known as keystones.

In the mobile ecosystem, there are multiple firms who are trying to position their mobile OS as the dominant platform, each with different value propositions for why other firms would want to align with them. As such, there is no clear winner or pre-dominant platform in this ecosystem yet and it would be interesting to observe how the ecosystem changes over time, until such a platform becomes clear. What would be even better,

especially for the firms that are looking to make an investment decision to go with one OS platform over the other, would be to be able to predict and analyze, based on currently available information, which OS they should put their investment dollars in. An interesting multi-disciplinary approach to solving this problem would be to consider Axelrod & Bennett's (1993) Landscape Theory of Aggregation, which has been widely used to predict alliances for World War 2, the airline industry, and UNIX standards setting. This theory takes a few variables related to the clout of each "actor" in the system (**Size**) and their tendency to ally with all other actors in the system (this is said to determine their **Propensity** to work together). Using the Size and Propensity measures, the optimal alliance for the actors in a system can be determined.

Applying this to the mobile ecosystem, we can determine which mobile OS platforms various firms, be it mobile device manufacturers, mobile application providers or mobile network operators, should align themselves with in order for it to be most profitable for their business.

1.1 Objectives

This research aims to explore the application of landscape theory in the context of the mobile industry. The objective is to formulate a model which can be used to find optimal alliances between mobile platform providers (MPPs) and mobile device manufacturers (MDMs), and compare these to the actual alliances formed in the industry. Subsequent sections will explain how these two segments of the mobile ecosystem were chosen for analysis as well as how the original landscape model was adapted for use.

1.2 Deliverables

This paper aims to deliver an analytical tool that MPPs and MDMs can use to determine what their strategic cooperative and competitive stance should be. Specifically it allows mobile device manufacturers to view optimal alliance structures for themselves in relation to other device manufacturers and mobile OS platform providers. In this way, it benefits the various members of the mobile ecosystem.

1.3 Contribution

This research helps members of the mobile ecosystem, specifically mobile device manufacturers and mobile platform providers analyze the potential payoff of allying with each other.

It also provides validation of the concepts of landscape theory in a new application i.e. the converging mobile ecosystem, thereby advancing the work on Axelrod's landscape theory of aggregation by applying it to a new industry.

1.4 Organization

This paper is organized into five chapters.

Chapter 2 provides a selective literature review of the related streams of interest – including the theoretical foundation as well as the latest research on the mobile phone industry.

Chapter 3 describes how the mobile landscape model was developed from the observations and lessons learned from the literature review. The chapter also describes the data collected and how it was used in the model.

Chapter 4 shows the predicted and optimal alliances that were obtained based on the information entered into the mobile landscape model that was developed in the previous chapter. These results are compared to the existing information and visualizations of the ecosystem that are available.

Chapter 5 explores how a further refinement of the landscape model results in more accurate alliance predictions.

Chapter 6 summarizes the results and discusses the limitations of the research. Avenues for further research are suggested.

2 Chapter: Literature Review

The literature on this research topic splits into two main areas – the theoretical basis consisting of business ecosystems and landscape theory of aggregation, and research on the mobile industry, particularly mobile OS platforms.

2.1 Business Ecosystems

The literature on business ecosystems considers the application of the biological ecosystem concept in the field of management and social sciences. This stream looks at the definition of what a business ecosystem is and its purpose, and what distinguishing properties and features it has.

2.1.1 Definition and Purpose

Moore (1993) initially defined the business ecosystem to mean companies that cannot be viewed as a part of a single industry but span a variety of industries. In this system, companies depend on each other to drive cycles of "reciprocal innovation", which is termed co-evolution. Co-evolution encompasses both collaborative and competitive actions between firms in the ecosystem. Iansiti and Levien (2004) further elaborate on this concept stating that ecosystems also include those collaborations between companies that fall outside of the traditional value chain roles of supply and distribution, once again indicating the broad range of business domains that a single ecosystem encompasses. However, they point out that drawing the precise boundaries of an ecosystem is an impossible task, given the complex, intertwined relationships between members. At best, they recommend that a firm closely examine its critical dependencies to determine the most important relationships it has in the ecosystem.

Moore (2005) refines the ecosystems concept to be the third organizational structure for business, after markets and hierarchies. He further expands on the concept of co-evolution by proposing that an ecosystem is a plan for how the contributions in a proposed system will be modularized, and what sorts of firms will provide which element. Hargadon (2002) agrees on this concept, describing innovation as a construction of new ideas from existing ones. From this perspective, the ecosystem is an infrastructure where the mastery of various modules by individual firms can allow easier recombination. This provides shorter learning curves, the sharing of past experiences across organizations and brings diversity to the innovation process (Weiss & Gangadharan, 2009).

Moore (2005) also introduces two key analogies for the structure of ecosystems. The first describes the ecosystem as a **landscape of contributors**, with various groups encircled in interpenetrating Venn diagrams representing the many such sets within the system. In the second, Moore states that business ecosystems can be viewed as having a politics similar to a political party, where a coherent vision is possible as long as members have largely overlapping views. This is what enables successful innovation to be carried out. At the same time, complete unification in views is not desirable as it reduces the total diversity of ideas within this innovation system.

2.1.2   Ecosystem Structure

The second key area of research in the business ecosystem literature stream is that of the ecosystem infrastructure and its properties.

Moore (1993) describes the business ecosystem as having stages of evolution consisting of birth, expansion, leadership and self-renewal. Figure 1 below, shows a diagram explaining the cooperative and competitive directions that need to be adopted by the firm in each stage of the evolution.

Cooperative Challenge:
Define Value Proposition
Seed Ideas
Competitive Challenge:
Protect Ideas
Tie up with customers, suppliers, and channels

Birth

Cooperative Challenge:
Bring offer to market
Get maximum market share
Competitive Challenge:
Ensure offer is the market standard

Self-Renewal

Expansion

Cooperative Challenge:
Innovate to bring new ideas to Ecosystem
Competitive Challenge:
Maintain high barriers, high switching costs to prevent dilution of customer base

Leadership

Cooperative Challenge:
Provide compelling vision bringing together suppliers and customers
Competitive Challenge:
Maintain strong bargaining power

Figure 1: The Evolutionary Stages of a Business Ecosystem (Moore, 1993)

Moore (1993) mainly explores ecosystems from the perspective of companies who are looking to become what he calls "central ecological contributor". These are those firms that provide a key innovation to the ecosystem, without which other members could not survive. Other firms join to provide "genetic diversity" to the system.

Iansiti and Levien (2004) provide a more detailed taxonomy of ecosystem members, in terms of the strategic roles they can adopt. They relabel the central ecological contributor as the **keystone**. The keystone aims to improve the ecosystem by providing a stable and predictable set of common assets. The keystone and other members of the ecosystem are described in Table 1. The role the firm adopts determines the strategy that it implements as part of the ecosystem.

Table 1: Strategic Roles within a Business Ecosystem (Iansiti & Levien, 2004)

Role	Characteristics
Keystone	Provides a stable and predictable set of common assets Assumes responsibility of connecting network participants to one another
Physical Dominator	Integrates horizontally or vertically to directly own and manage a large proportion of a network Responsible for creating the value they capture
Value Dominator	Has little direct control over its ecosystem Creates little value while extracting as much as possible
Niche Player	Develops specialized capabilities that differentiate it from others Leverages complementary resources to enhance narrow domain of expertise Responsible for most of the value creation and innovation in the system

The strategy that individual firms choose as ecosystem participants directly affects the health of the ecosystem. The three critical measures of ecosystem health are productivity, robustness and niche creation (Iansiti & Levien, 2004). Productivity refers to the system's ability to consistently transform technology and other innovation raw materials new products with lower cost. Robustness speaks to the ability of the ecosystem to survive disruptions such as those brought about by unforeseen technological change. Niche

creation considers the capacity to increase meaningful diversity through the creation of value new functions within the ecosystem. Measures of all three are provided by Iansiti and Levien (2004).

2.2   Landscape Theory of Aggregation

Introduced in Axelrod et. al. (1991) and Axelrod and Bennett (1993), landscape theory of aggregation is a model that predicts how actors in a system will form alliances with others, given the choice of two possible alliances. This terminology is not to be confused with the energy landscape model, which is used extensively in the biological and physical sciences to study protein folding and molecular behavior. The two models are related in that they both study ways in which systems can achieve their most stable state or configuration.

2.2.1   Constructs

There are two assumptions made by the original landscape theory (Axelrod & Bennett, 1993). The first is that each actor has a myopic viewpoint, meaning that it can only evaluate its relationship with any one other actor at a time, independent of all the other actors in the system. The second assumption is that adjustments to coalitions take place by incremental movement of individual actors, ruling out the possibility that a sub-alliance may form within a coalition and then switch allegiance as a block.

The theory has three key constructs of size, propensity and distance, which are defined in Table 2.

Table 2: Constructs of Landscape Theory

Construct	Definition
Size (s_i)	A reflection of the importance of actor, $\boldsymbol{i}$, to others.
Propensity (p_{ij})	The willingness of two actors to cooperate. The theory assumes that propensity is symmetric - $p_{ij} = p_{ji}$
Distance (d_{ij})	A measure of whether two actors are in the same alliance structure or not – if the actors are in the same alliance, then the distance between them is assigned to be 0, if they are in different alliances, the distance is assigned to be 1. Distance is calculated for each possible alliance configuration, given a certain number of actors, $\boldsymbol{n}$.

Size is a reflection of the importance of an actor in the system. In order to form the largest alliance for itself, an actor will try to align with as many large actors as possible. The assumption here is that a larger alliance will have increased clout and collective resources to influence outcomes in their favor than a small alliance would.

Propensity is the other parameter in the model and it measures the willingness of two actors to work together. Actor I might be of a large size but if actor J has a negative propensity to work with I, then J will likely try to position itself as far away from I as possible i.e. is the other alliance. Thus, even though J would like to be a part of the largest alliance, it will at the same time want to avoid being in the same alliance with actors that it has a negative propensity to cooperate with. In this way, the Size and

Propensity influence the actors in differing ways as they try and arrange themselves into optimal alliances.

Given the definitions for Size and Propensity, it is then possible to determine the utility function, $U_i(A)$, for each actor, i, in the system, i.e. the payoff function of the actor. **Utility** for actor I is defined as the sum of the size of each of the other actors multiplied by their propensity to cooperate with I.

$$U_i(A) = \sum_{j \in A} s_j p_{ij},$$

Figure 2: Definition of Utility Function (Axelrod et. al., 1995)

An alliance structure is a particular partition of all the actors in the system such that each actor is in one and only one grouping. Landscape theory is defined only for a maximum of two possible alliances within the system, with actors being a member of either one or the other, but not both.

For example, in a system with 4 actors and 2 possible groups that they can belong to, there are 2^3 or 8 unique configurations for possible alliance structures. Once defined, size and propensity are independent of alliance structure. However, **distance** is dependent on it and will change with each configuration. For each possible configuration, a different distance matrix will be generated, as the actors will be organized in different groups each time.

All possible configurations are iterated through to find the one in which the weighted sum of the utilities of each actor is minimized. This is called the energy of the system, E(X).

$$E(X) = \sum_i \sum_j s_i s_j p_{ij} d_{ij}(X),$$

Figure 3: Definition of Energy Function (Axelrod et. al., 1995)

The lower the energy of a configuration, the more optimal it is as an alliance structure. This is achieved by, as far as possible, placing firms that have negative propensities to work together in opposing alliances (so that the distance between them is 1 as opposed to 0) as this will result in lower energy values (negative real numbers). The effect is multiplied if the firms are both also large in size.

By mapping the energy values for each possible configuration, an energy "landscape" can be generated, which is where the name of the theory comes from. The configuration or configurations which compute to the lowest energy value are the ones that the landscape model puts forth as the "optimal" arrangement of the actors into alliances. Axelrod et. al. (1995), show that these optimal alliances correspond to the local minima of the energy function. The local minima are also stated in the same paper to be the Nash equilibria solutions of the problem, with Nash equilibria being a solution concept used in game theory to find best decision a player can make given a priori knowledge of all the other players' decisions. This is a significant result since Nash equilibrium solutions mean that the player has knowledge of other players' actions, while in the landscape model no such information is known to an individual player. Thus it speaks to the power of the landscape model in being simple yet effective tool for determining optimal alliance structures.

Local minima indicate the most viable and stable configurations, making the particular coalitions described by that configuration more likely. A further implication is that if multiple local minima occur, the one into which the system settles can depend on the history of the system i.e. what the initial configuration looks like (Axelrod et. al. 1995).

2.2.2 Extensions and Applications

Axelrod and Bennett (1993) first applied landscape theory to the World War Two coalitions of Allies and Axis powers and the same theory was applied in a standard-setting scenario by Axelrod et. al. (1995), who used it to show its predictive ability in what are known as the UNIX standard setting wars.

The application of the theory to the Unix wars is carried out by deriving Size values for the 9 firms in the ecosystem from their market share and revenue information. Additionally, their propensity towards each other is measured by classifying them into close and distant rivals, where close rivals have an increased negative tendency to ally (Axelrod et. al, 1995).

Murata and Kijima (2005) extended the original landscape model by introducing dynamic and external parameters. They apply the landscape theory to the airline industry and examine alliances within the industry after introducing the external parameter of reputation to influence the actions of the actors. They do this by linking them to the marginal value that each actor brings to the alliance.

Le Breton et. al. (2007) further strengthens the link between the landscape model and study of coalition forming games in the realm of game theory.

2.3   The Converging Mobile Ecosystem

Besides the theoretical basis of this research, it was important to study the current literature on the mobile industry, especially where either business ecosystems or landscape theory had already been applied. For completeness, a timeline was also compiled to show the key milestones shaping the growth and evolution of the mobile ecosystem.

2.3.1   Mobile Industry as a Business Ecosystem

There is significant precedent of the mobile industry being described as an ecosystem with multiple firms in a variety of value segments (Basole, 2009b; Lin and Ye, 2009; Basole and Karla, 2011; Kenney and Pon, 2011). Basole(2009a) points to the convergence occurring in the mobile industry, with traditionally separate industries such as the Internet, cable, gaming and entertainment coming to mobile devices and thus creating a race to create compelling, integrated mobile products and services, and capture a piece of the revenue streams in this lucrative new market. Basole (2009a) defines this as the converging mobile ecosystem.

Basole (2009a) and Lin and Ye (2009) both characterize the firms within the industry into different value segments. While Lin and Ye (2009) use the "food web" ecosystem

concept to describe the roles played by various firms that show their links to the end-user or customer, Basole uses two main categories – current segments and emerging segments to define the segments to which the firms of the converging mobile ecosystem belong to. Both segmentations are shown below in Figure 1, with the left hand side showing Lin and Ye's (2009) model and the right hand side showing Basole's model of the converging mobile ecosystem, with the light grey circles indicating current segments and dark grey circles depicting emerging segments.
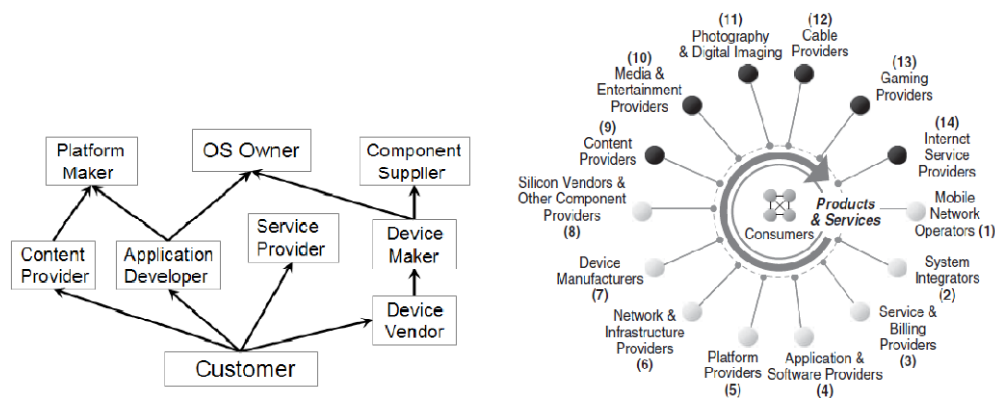
Figure 4: The Food Web and Converging Mobile Ecosystem Models of the Mobile Industry (Lin & Ye, 2009; Basole, 2009b)

Of the segments that Basole (2009a, 2009b) identifies, he names four of them as the key players in the mobile ecosystem – Mobile Platform Providers (MPP), Mobile Device Manufacturers (MDMs), Mobile Network Operators (MNOs) and Mobile Application Developers (MADs).

Of these, MPPs are repeatedly described in the literature (Basole, 2009b; Kenney, 2011) to be playing the role of broker in the mobile ecosystem, and due to their role in

providing the technology platform for other value segments, drive other value chains in the mobile space. With each mobile platform acting as a hub, several platform- centered ecosystems are forming within the overall ecosystem. A visualization of ecosystem over time shows this very phenomenon (Basole, 2009b).

There are also extensive studies on the technological capabilities of the major mobile OS platforms currently, namely, Symbian, Android, Windows Mobile and iOS. Some papers (Godwin-Jones, 2008; Ghandewar & Sheikh, 2010) even compare the mobile OS platforms head to head across various categories, including portability, connectivity and kernel size.

In additional network analysis carried out by Basole and Karla (2011) (shown in Table 3), MNOs are shown to be interacting with an increasing number of MPPs over time, with interactions with 2.5 platforms per MNO in 2006 up to 4.5 in 2010. In the same time period, MDMs are tending to interact with 1 to 2 MPPs, with the mean degree metric being between 1.1 and 1.8 platforms per MDM.

Table 3 Network Analysis Results for MNOs and MDMs (Basole & Karla, 2011)

	2006	2007	2008	2009	2010
Mobile Network Operator					
- Mean Degree (S.D.)	2.412	2.794***	3.588***	4.176***	4.500***
	(0.701)	(0.946)	(1.076)	(1.314)	(1.187)
- min/max	1/4	1/5	1/6	1/7	2/7
Mobile Device Manufacturers					
- Mean Degree (S.D.)	1.100	1.455*	1.652**	1.577	1.714**
	(0.308)	(0.963)	(0.982)	(0.945)	(0.976)
- min/max	1/2	1/4	1/4	1/4	1/4

There is significant research in the mobile application development space, with the main highlights being studies on how MPPs can attract MADs to their app stores (Lee et. al., 2010), as well as how networks effects and overcrowding affect innovation by the MADs (Boudreau, 2011).

2.3.2   State of the Mobile Industry and Milestones

For better understanding and to aid the discussions of the results of the research, a description of selected milestones for the mobile industry over a period from 1998 to 2012 are shown below.

24/06/1998
Symbian Ltd launched
Nokia is majority partner

19/04/2000
Microsoft launches Windows Mobile

29/06/2007
Apple launches iPhone

05/11/2007
Open Handset Alliance,
led by Google, launches Android

24/06/2008
Nokia acquires Symbian.
Symbian launches with EPL license
as free and open software

31/07/2008
Distinction between feature phone
and smartphone is first made

20/09/2008
HTC Dream is first Android
Phone launched

18/07/2009
Nokia hands over Symbian to
Accenture

01/06/2010
Samsung launches new
Smartphone with
in-house Bada OS

08/11/2010
Windows Phone OS succeeds
Windows Mobile

01/12/2010
Android overtakes Symbian in
OS market share.
Samsung becomes largest
Android phone maker

16/02/2011
Nokia partners with
Microsoft

29/07/2011
Apple becomes world's
largest smartphone vendor

02/09/2011
Baidu launches Android fork
the Yi OS

23/11/2011
China becomes largest
smartphone market,
overtaking the US

24/04/2012
Samsung overtakes Nokia
as world's largest
cellphone vendor

Figure 5: Timeline of Mobile Industry Milestones

2.4   Observations and Learning

The main lessons learned from the literature review are summarized below.

2.4.1   Mobile Industry as a Business Ecosystem

The mobile industry can be viewed as a business ecosystem, which is characterized as an alliance of firms seeking ways to gain sustainable competitive advantage by collaborating with each other to obtain the benefits of recombinant innovation.

While there are some high level ideas about ecosystems, their properties, infrastructure and purpose, there is little in the way of empirical research on ecosystems and it is difficult to operationalize the extensive theoretical studies on the topic.

A review of the business ecosystem literature shows that there is a lack of research on how an ecosystem member would strategically choose allies and form alliances.

2.4.2   Parallels between Business Ecosystems and Landscape Theory

Given the indications in Moore's (2005) paper that alliances in an ecosystem are much like the maneuverings of members of a political coalition, an interesting parallel is drawn to the landscape theory of aggregation,(which was initially used as a model to study World War Two political alliances) as a framework with which to examine these coalitions.

Landscape theory gives constructs, such as size and propensity, which, when defined to reflect the industry in question, can lead to greater predictive and analytical capability

about possible coalition formations. This may help explain the current and future state of the converging mobile ecosystem.

2.4.3   Prior Application of Landscape Theory to Standards Setting Alliances

The application of landscape theory to the Unix Wars in Axelrod et. al (1995) is especially interesting as it showed the applicability of the landscape model to an industry where standards are used as platforms upon which industry members create value added services and products.

This industry structure is common across the mobile infrastructure business (with standards such as GSM, CDMA and LTE), the Internet (standards include HTML, various social media platforms, content delivery platforms etc.), and the mobile handset industry (where the literature shows that mobile OS platforms are becoming the standard upon which other firms innovate).

This gives further increases the expectation that landscape theory can be used to model the mobile industry as successfully as was done in the Unix Wars case and provides a precedent on how to operationalize model constructs such as size and propensity.

2.4.4   Existing Analysis of the Mobile Ecosystem can help to formulate a Landscape Model for the industry

Existing visualization and network analysis of the mobile ecosystem offers insights into which value segments to consider, to begin building a landscape model for the mobile industry.

Firstly, in the visualization, MPPs emerge as the key hub around which the ecosystem is beginning to structure itself. Secondly, the central segments of the converging mobile ecosystem seem to be MNOs, MADs and MDMs.

MPPs

Thirdly, the network analysis shows that MDMs will tend to ally with 1 to 2 MPPs at most, which can be attributed to the fact that they will face higher development complexity and costs for each additional mobile operating system (OS) they choose to use. Depending on the mobile OS chosen, there can be associated development costs to customize the OS, and offer MDM specific applications, or licensing costs that the MDM has to bear for each phone they launch with a particular OS platform.

Mobile OS selection decisions have less bearing on MNOs, as these firms would like the most variety of phone offerings for their customers in order to appeal to different market segments and gain as large a subscriber base as possible

Although not discussed in Basole's research, it can be speculated that MADs will act like MNOs and offer their application software on as many platforms as possible in order to reach a wider customer base. This is possible due to the lower development and startup costs offered by most of the leading MPPs, through providing rich APIs, integrated development environments (IDEs) and developer support forums for their mobile OS platforms (Boudreau, 2011).

2.4.5 Limitations of Landscape Theory Model

Some limitations in the theory are apparent, the chief one being that the model is

designed to deal with a maximum of two alliances at a time. In the study of mobile

ecosystem thus far, it is clear that there are multiple alliances that are possible, especially

with the advent of the new wave of mobile OS platforms like iOS and Android. A

strategy to incorporate these multiple alliances into the model would need to be

developed.

3   Chapter: Research Methodology

The research methodology requires combining the learning on landscape theory and the converging mobile ecosystem from the literature review to develop and operationalize the landscape theory model for the mobile industry. This involves a discussion as to which actors are considered in the model, how alliances between them are defined and the practical aspects of the research design, including how the data was gathered and processed.

3.1   Choosing firms for the Mobile Landscape Model

At this point, it will be helpful to restate some key observations from the literature review that are used to determine the actors or firms to be studied with the mobile landscape model, and thus define the scope of the research.

3.1.1   MPPs are keystones or hubs in the mobile ecosystem

Firstly, the visual representations of the mobile ecosystem over 2006-2010 (Basole, 2011) and the description of ecosystem keystones in the literature both point to Mobile Platform Providers (MPPs) as the likely hubs in the converged mobile ecosystem going forward. It is the MPPs that provide the key element (mobile OS platform) in the value chain that is used by other firms to derive revenue, whether it is network operators, device manufacturers or any of a variety of content developers and distributors. Thus, in a landscape model, MPPs are likely to be the firms around which alliance structures form.

3.1.2   MNOs, MDMs and MADs are the other central segments of the mobile ecosystem

Besides the MPPs, Mobile Device Manufacturers (MDMs), Mobile Network Operators (MNOs) and Mobile Application Developers (MADs) are the other three important segments in the converging mobile ecosystem (Basole and Karla, 2011). While MDMs and MNOs have traditionally been important segments of the ecosystem, MADs are a new segment, brought to the forefront by the emergence of application-based software development for smartphones.

3.1.3   MDMs interact with only 2 MPPs at the maximum

Based on the network analysis carried out by Basole (2011) (shown in Table 4 of the last chapter), MNOs interact with an increasing number of MPPs over time, while MDMs are tied to just 1 to 2 MPPs, with the mean degree metric being between 1.1 and 1.8 platforms. It can be concluded from this that MDMs will be more concerned with making the right choice for MPP than the other two major segments of the converging mobile ecosystem, the MNOs and MADs, since there are significant costs associated with mobile OS platform adoption.

Thus, MDMs are best suited to be included in the landscape model, since it is designed to show preference for one alliance over another i.e. a firm cannot be a member of two different alliances (in this case, we are modeling it such that each MPP will be a hub around which an alliance will form).

3.1.4   Only some MPPs have licensable mobile OS platforms

Another critical differentiating point in how MNOs and MADs adopt Mobile OS platforms as compared to MDMs is that of the different MPP platforms that exist in the ecosystem, only some can be used by MDMs on their own handsets. For example, Apple and Research In Motion both produce mobile OS platforms, the iOS and Blackberry OS

respectively. However, these platforms are proprietary and only used in the companies' own products. As such, they are not potential platforms that can be adopted by MDMs. However, MNOs and MADs can still choose to sell these phones or develop applications for these platforms respectively.

Therefore, of the mobile OS platforms that are available in the ecosystem, only some can be licensed to be used by MDMs. Thus, in the landscape model, only those MPPs that are licensable are considered, since MDMs cannot adopt or ally with closed mobile OS platforms such as iOS or Blackberry OS.

3.1.5   Conclusions

Given the above observations about the converging mobile ecosystem, only MDMs and licensable MPPs are considered in the mobile landscape model.

 Since MNOs and MADs are likely to adopt many if not all MPPs for use in due course, it is of more value to study how MDMs will go about choosing the mobile OS platforms that it will use in its mobile phones. Thus **our model only considers licensable MPPs and MDMs and their relations in the mobile ecosystem** i.e. which MPP will an MDM pick to form an alliance with.

MPPs are considered to be the hubs around which alliances will form and they have a strong tendency to compete with each other. As such, **there will be as many alliances formed as there are MPPs**. For example, if there are 3 MPPs in the model, then 3 alliance groups will be defined, each centred around a MPP. All the MDMs are then free to ally with the MPP and other MDMs with which they can achieve the lowest energy i.e. the most stable configuration.

Since the landscape model will ensure that an MDM is only paired with one MPP at any time, if the reality is that an MDM does pick two or more MPPs, then the model should return the one it uses the most i.e. in more of its phones.

3.2   Multi Alliance Landscape Model

Given the multiple mobile OS options for an MDM, there would need to be a way to predict the alliances for multiple platforms. The landscape model, as it is described in the literature, is designed to allow all the actors to choose one from at most two possible alliances. Since each mobile OS platform is modeled as a separate alliance option, and there are more than 2 mobile OS choices for MDMs in some cases, application of the model to the mobile ecosystem would require an appropriate extension to the basic landscape theory model so that the firms can choose one from multiple possible alliances. Two possibilities as to how multiple alliances could be studied via landscape theory are described in the section below.

3.2.1   Deconstruction of Multiple alliances to Pairwise Comparision

The first was to deconstruct the multiple alliance problem into the pairwise consideration of all the MPPs against each other. Therefore, if there are three MPPs considered – Symbian, Microsoft and Google, then the original 2 alliance landscape model would be used to do a pair by pair analysis of how the MDMs will ally.

This approach is tricky because once the pairwise alliances are determined, it is difficult to combine the results to obtain the final three alliances. For example, in a system where there are 5 players, 3 MPPs (A,B and C) and 2 MDMs (D and E), there will be three pairwise comparisions carried out: A against B, A against C and B against C (D and E

will be part of all three models). Figure 5 shows an example of the results that can

obtained when taking this approach.

Comparison 1		
A and B:		
Alliance 1	Alliance 2	
A	B	Energy: -100
E	D	

Comparison 2		
A and C:		
Alliance 1	Alliance 2	
A	C	Energy: -200
D	E	

Comparison 3		
B and C:		
Alliance 1	Alliance 2	Energy: -150
B	C	
E	D	

Figure 6: Sample results of Pairwise Comparison of MPPs

From the Figure above, it is hard to conclusively determine what the alliance structures

will be once all three alliance possibilities (A, B and C) are considered. One can argue,

that since the energy of the A and C comparison (Comparison 2) is the lowest (Energy is

-200), that it is the most stable configuration (i.e. A aligns with D and C aligns with D).

However, this does not account for how B affects the system, with Comparison 1

suggesting that the addition of B will result in E aligning with A, while Comparison 3

suggests that it will result in E aligning with B.

This simple scenario shows that it is possible to have inconclusive final results by taking

this approach to modeling multiple alliances.

3.2.2   Manipulation of the Distance in existing Landscape Theory Model

Another approach to solving the problem of modeling multiple alliances in landscape

theory is to consider how distance is defined in the theory. As shown in Table 2, distance

is defined as 0 if two firms are in the same alliance and as 1 if they are in differing

alliances. This definition can be extended to 3 or more alliances by defining distance as 0

if two firms are in the same alliance and as 1 if they are in any other alliance than the

same one. However, this approach significantly complicates the automation of

mathematical calculations, since 3 alliances mean upto $3^{(n-1)}$ different configuration

scenarios, given n firms in the system.

 Similarly, for x alliances, upto $x^{(n-1)}$ configurations must be considered and the

corresponding energy values for each calculated.

An example of how the distance matrix is determined is shown in the Figure below.

	Actors in the System	One Possible Configuration	Distance Matrix

A, B, C, D

A   C   D
B

One of $3^{(4-1)} = 27$ possible configurations

	A	B	C	D
A	0	0	1	1
B	0	0	1	1
C	1	1	0	1
D	1	1	1	0

Distance matrix will change with each of the 27 configurations
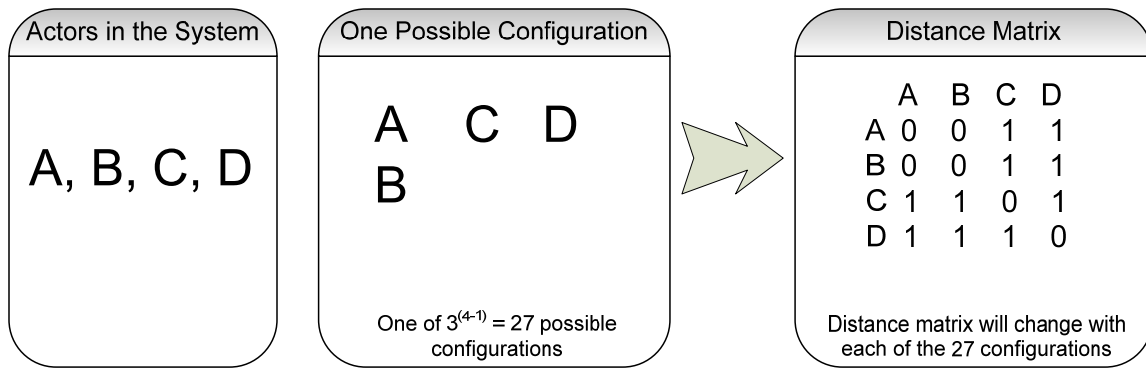
Figure 7: Example of Distance Matrix Calculation

The figure shows how the distance matrix is calculated if there are 4 actors in the system, and they are arranged in a certain configuration. Since A and B are in the same alliance, the distance between them would be 0. They would have a distance of 1 from C and D, as they belong to different alliances. Similarly, the distance of A, B and D from C is 1, since they all belong to different alliances. The result is a 4x4 distance matrix for each configuration (for 4 actors, there are 27 possible configurations, or arrangements of actors into 3 alliances).

In email consultation with Dr. Axelrod, we agreed that this second approach was cleaner and more attractive in that it considered all alliances simultaneously. The automation complexities were solved by using matrix mathematics. How the automation was carried out is described in the Appendix.

The above decisions (in section 3.1 and 3.2) helped to narrow the research problem down to how MDMs will go about aligning themselves with MPPs to form alliances.

3.3 Research Design

As discussed above, the unit of analysis of this research was a MDM determining which MPP to adopt by using the landscape theory model, appropriately operationalized for the converging mobile ecosystem. The complete description of the model is given in subsequent sections.

With the model year to year data from the period from 2006 to 2010 was used to determine what the optimal alliance structures for each year would have been. The results from the model were compared to the visualization data for the same 5 year period given in Basole and Karla's research (2011) and other data gathered from Internet sources for verification.

In each year period, a list of the MDMs was gathered based on those who have a significant share of the market. A 1% or greater share was considered to be a significant share of the total mobile market. This information is available through internet data and market research firms such as Gartner.

A list of MPPs were also be gathered from Basole's visualizations and market share data., again available through internet data from Gartner. Only those MPPs that had licensable operating systems were considered. The type of licensing model the MPP employed was not considered, and ranged from an open source license to a per use royalty-based license. As such, Apple's iOS, although popular with MNOs and MADs, will not be a

valid mobile OS platform to consider for MDMs as it is not available for use outside of Apple's own products.

3.3.1   The Mobile Landscape Theory Model

Once the sample set (list of MDMs and MPPs) is complete, the next step was to operationalize the various constructs of landscape theory. The theoretical foundation and equations given in Axelrod & Bennett (1995) were used as a basis for this research. The formation of Unix Standards alliances discussed in that paper and our attempt to find the mobile OS platform standards that will be used in the mobile ecosystem are similar in nature, which makes this theoretical foundation a good one on which to base a model for the mobile industry.

For operationalization, the individual firm size and the propensity of all the firms in the system to work with each other had to defined and measured. As was shown in Table 3, size is a reflection of the importance of a firm to others in the ecosystem. In the Unix Standards setting case (Axelrod & Bennett, 1995), size is measured through the market share and revenue, which would be appropriate measures in the case of the mobile ecosystem members as well, as they provide a good indication of influence of the various firms. Market share is a common indicator of firm performance in the mobile industry, making it an easy metric to obtain as well as an important indicator of firm "clout" in the ecosystem. Similarly, revenue of a MPPs mobile divison indicates the investment capability that a firm may have to launch and establish a mobile OS platform through providing the software development kits (SDKs), support forums and application stores or marketplaces to fully develop the value network around the platform.

In the case of MDMs, operating profit is a good indicator of the money a firm has to re-invest into the R&D activities of developing new mobile phones, which will also involve choosing the mobile OS platform for the handsets. These size measures are described in the equations below

$$Size_{MPP} = \tfrac{1}{2}(Market\ Share) + \tfrac{1}{2}(Revenue)$$

$$Size_{MDM} = \tfrac{1}{2}(Market\ Share) + \tfrac{1}{2}(Operating\ Profit)$$

Figure 8: Equations for Size

Equal weightage was given to the market share and revenue (in the case of MPPs) or operating profit (in the case of MDMs) to come up with a Size value for each of the MPPs and MDMs which are part of the study. The Size value will change from year to year as the revenue, operating profit and market share data vary annually.

The data points for the market share, revenue and operating profit were obtained from the annual reports and tax filings of the publicly listed companies that were studied. If the companies were not public, then press releases and news stories were used to gather the information.

For propensity, the model in Axelrod & Bennett (1995) also fit the research sample nicely. In that paper, Unix companies were divided into specialist and generalist firms based on their product and service portfolios. Axelrod and Bennett speculated that firms falling in the generalist category would have an increased negative propensity to working with other generalists, since they would compete across many products and services (defined as close rivals), while a specialist and generalist would have a less negative

propensity to work (defined as distant rivals) Similarly, there are two firm segments in the research problem we are considering – MPPs and MDMs, which have differing roles in the ecosystem. The propensity for MPPs and MDMs (distant rivals) to work together would be less negative while MPP-MPP and MDM-MDM (close rivals) propensity would be more negative. Another way to look at this would be to view MPPs to be close rivals of other MPPs, and MDMs to be close rivals of other MDMs. MPPs and MDMs would be distant rivals of each other. This is directly related to whether a firm will adopt a competitive or cooperative stance towards another. In the case of an MPP, we make the simple observation that it will most likely compete with another MPP, which has a directly competing market offer, while cooperating with a MDM, which has a complementary asset which, if it uses their mobile OS platform, would help strengthen their ecosystem. The reverse case would apply to a MDM, i.e. it will cooperate with a MPP while competing with another MDM. In the case of the Unix wars, the propensity of distant rivals was modeled as [1- α], while close rivals were modeled as [1 - (α+β)].The equations below show this information as a formula:

$$\text{Propensity}_{\text{MPP-MPP}} = [1 - (α+β)]$$
$$\text{Propensity}_{\text{MPP-MDM}} = [1 - α]$$
$$\text{Propensity}_{\text{MDM-MDM}} = [1 - (α+β)]$$

Figure 9: Equations for Propensity

In the equations above, we use the value of 1 for alpha and beta, as it is used in Axelrod et. al (1995). Substituting the alpha and beta values into the propensity equations above, would give the following basic propensity values:

$$\text{Propensity}_{\text{MPP-MPP}} = [1 - (α+β)] = [1 - (1+1)] = -1$$
$$\text{Propensity}_{\text{MPP-MDM}} = [1 - α] = [1-1] = 0$$

$$\text{PropensityMDM-MDM} = [1 - (\alpha+\beta)] = [1-(1+1)] = -1$$

In order to use the existing landscape model for more than 2 possible alliance choices, as discussed in section 3.2.2., (i.e. where a MDM can choose between multiple OS platforms such as Windows Phone, Android and Symbian, for example), we define distance as follows:

$$\text{Distance, } D_{ij} = \begin{cases} 0, \text{ if i and j are in the same alliance} \\ 1, \text{ if i and j are not in the same alliance} \end{cases}$$

To measure distance, we use the same algorithm as described in section 3.2.2, with distance 0 denoting two firms in the same alliance and distance 1 denoting that they are in different alliances. Note that if there are three MPP groups, say Group 0, Group 1 and Group 2, and Firm A is in the Group 0 alliance and Firm B is not, then the distance between Firms A and B is 1. It does not matter whether Firm B is in Group 1 or Group 2 in order to calculate the distance between A and B.

Propensity values were easy to generate as the companies just had to be classified as a MPP or MDM. This information was known but was also verified by reviewing the product offerings of the various companies. This information was readily available on the Internet through the company website and sites such as Wikipedia.

In order to do the calculations, an automation script was written in R (language and environment for data manipulation and calculation) that converted inputted size and propensity values into *1xn* and *nxn* matrices respectively, with *n* being the number of

firms being considered in the model. The script then generated all the possible alliance structures given n firms, and the distance matrix was generated. With the size, propensity and distance matrices, we can start to input them to the equations given to calculate the Utility and Energy (per firm and total for the system) per possible alliance structure. The script also determines where the lowest total energy of the system occurs, and gives the corresponding alliance structures. These are the local minima for system.

Note that the Utility and Energy equations for the total system are given as follows:

$$U_i(A) = \sum_{j \in A} s_j p_{ij},$$

where P_{ij} is the propensity of two firms to ally, is $[1 - (\alpha)]$ when i and j are distant rivals and $[1 - (\alpha+\beta)]$ when i and j are close rivals. These propensities are symmetric i.e. firms I and J have an equal tendency to want to compete/cooperate with each other.

The Energy function is the summation of all the Utility functions, weighted by the firm's size.

$$E(X) = \sum_i \sum_j s_i s_j p_{ij} d_{ij}(X),$$

As mentioned above, $d_{ij}(X) = 0$ when i and j are in the same alliance and 1 when they are in different alliances.

If there are n firms (MPPs and MDMs) being considered in the sample, where there are at most two MPPs, then there would be $2^{(n-1)}$ unique alliance structures possible in which to arrange n firms in 2 groups (alliances). These would all have to be iterated through to find those that give the lowest energy value for the system. The configurations with the

lowest energy are the optimal, or most stable. Similarly, in the case of three MPPs, there would be $3^{(n-1)}$ configurations to be considered, and so forth.

A copy of the R script and description of the matrix operations carried out are in the Appendix.

3.3.2 Size and Propensity Calculations

For each year, the data from the previous year is used to determine the size and propensity values. For example, for 2006, data up to the last day of 2005 is used. This would allow us to observe if the previous year's data can provide some predictive power on the future direction a firm will take with respect to choosing its' alliances.

For 2006, 2007,2008, and 2009, the MDMs (those holding at least 1% market share) considered were Nokia Corporation, Motorola Inc., Samsung Group, Sony Ericsson Mobile Communications AB and LG Electronics. Symbian and Microsoft were the MPPs involved, offering the Symbian operating system and Windows Mobile respectively until 2008, when Google introduced the Android operating system. (Note that Android is reflected only from 2009 onwards in the landscape model, since only data from the previous year is used)

For 2010, two new MDMs that held 1% or more market share in 2009 – ZTE Corporation and Huawei Technology Co Ltd - were added to the model.

Size and propensity values were calculated based on the equations given in Figures 6 and 7 above. The calculated size and propensities for 2006 (2 MPPs, 5 MDMs) and 2009 (3

MPPs, 5 MDMs) are shown below. The rest of the size and propensity tables for years 2007 through 2010 are available in the Appendix.

3.3.3 Example - 2006 Size and Propensity Values (2 MPPs, 5 MDMs)

Size:

2006	Revenue (millions USD)	Market Share	Operating Profit (millions USD)	Size
Microsoft	262	17		139.5
Symbian	114.8	51		82.9
Linux		23		
Nokia		34.9	5502	2768.45
Motorola		21.8	4605	2313.4
Samsung		11.7	2426	1218.85
Sony Ericsson		6.3	607	306.65
LG		6.8	441	223.9

Size for MPPs is calculated by taking into account revenue and market share, while for MDMs it was calculated using market share and operating profit. In cases where the company reported its revenue or operating profit in currency other than US dollars, the appropriate conversion was applied (using the closing exchange rate for the year before). The propensity table below is derived directly from the equations in Figure 7.

Propensity:

2006	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0	0	0	0
Symbian	-1	0	0	0	0	0	0
Nokia	0	0	0	-1	-1	-1	-1
Motorola	0	0	-1	0	-1	-1	-1
Samsung	0	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1

| LG | 0 | 0 | -1 | -1 | -1 | -1 | 0 |

3.3.4 Example – 2009 Size and Propensity Values (3 MPPs, 5 MDMs)

Size:

2009	Rev	Market Share	Operating Profit	Size
Microsoft	8140	11.8		4075.9
Symbian	291.7	52.4		172.05
Nokia		38.6	6718	3378.3
Motorola		8.7	0	4.35
Samsung		16.3	2190	1103.15
Sony Ericsson		7.6	124.5	66.05
LG		8.4	1136	572.2
Google	4227	0.5		2113.75

Note that for 2009, a new MPP was added – Google. The size calculations are all carried out in the same way. Note that in the case of an operating loss instead of profit for a MDM, the operating profit was entered as 0 (see Motorola example above).

The propensity table was generated using the Figure 7 propensity equations.

Propensity:

	MS	Symbian	Google	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	-1	0	0	0	0	0
Symbian	-1	0	-1	0	0	0	0	0
Google	-1	-1	0	0	0	0	0	0
Nokia	0	0	0	0	-1	-1	-1	-1
Motorola	0	0	0	-1	0	-1	-1	-1
Samsung	0	0	0	-1	-1	0	-1	-1
Sony E	0	0	0	-1	-1	-1	0	-1
LG	0	0	0	-1	-1	-1	-1	0

3.3.5　Data Processing and Calculations

Data processing and calculation was done using R, a software environment for data manipulation and calculation. Version 2.13.1 of the software was used, with an additional package (sfsmisc) loaded to provide access to additional functions. Further details and the R script can be found in the Appendix.

4 Chapter: Initial Results

The results were obtained from the mobile landscape models for 2006 through 2010 by applying the size and propensity values calculated to the utility and energy functions that are shown in previous sections. Based on the model, the alliance structures that result in the lowest energy are the optimal configurations. These are described in the *tables* below and compared to the visualizations generated by Basole (2009b) and Basole and Karla (2011) to see what the predictive value of the landscape model results is. The year by year visualizations from Basole and Karla (2011) are shown in the *figures* below with the relevant firms magnified to show their relationships.

4.1 Results – Base Model

4.1.1 2006

Table 4 Results of Base Landscape Model (2006)

Configuration 1		Configuration 2	
Microsoft	Symbian	Microsoft	Symbian
Nokia	Motorola	Motorola	Nokia
Sony Ericsson	Samsung	Samsung	Sony Ericsson
LG			LG
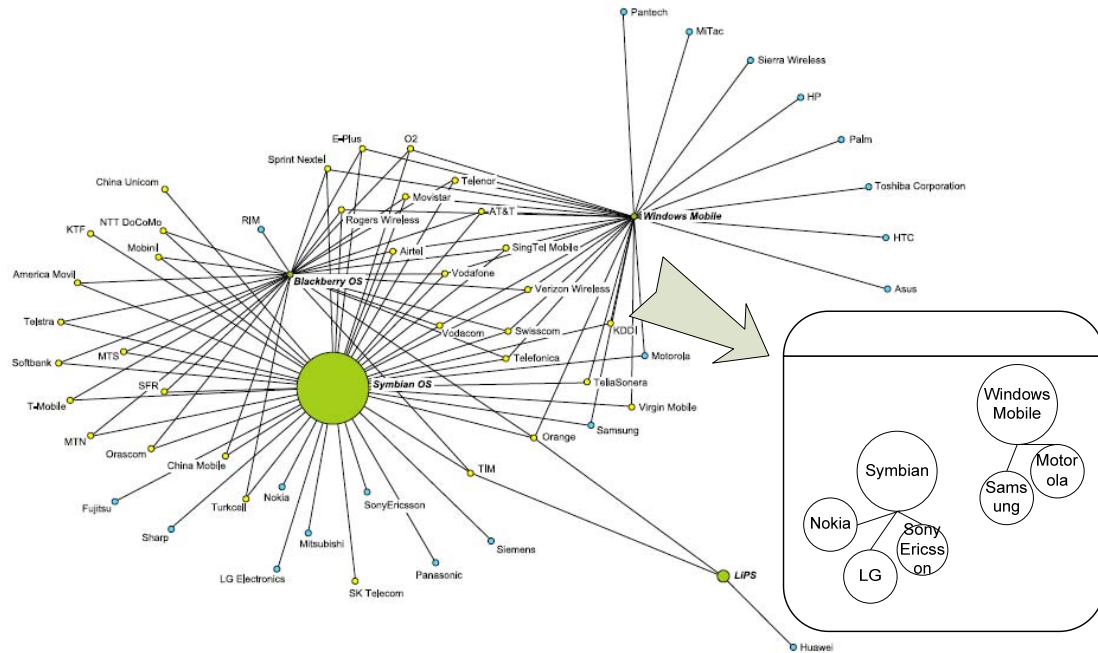
Figure 10: Visualization of Mobile Ecosystem, 2006 (Basole, 2009b)

For 2006, two possible optimal alliance structures resulted from the landscape model. Of these, we can make the following observations. Motorola and Samsung, the number two and three largest MDMs by market share will have a tendency to position themselves in an alliance separate from Nokia, the number one MDM. Smaller players such as Sony Ericsson and LG will tend to align themselves with the largest alliance i.e. the one that has the largest size. In this case, that would mean that they align with Nokia, which is the single biggest MDM in terms of market share and operating profits in 2006, even though they have a negative propensity to align with a competing MDM.

While clearly showing their affinity or distancing from the other MDMs in the system, neither of the MDM firms show a preference for one MPP or the other, This is due to the

fact that MPP-MDM propensity is assigned a value of 0 (or neutral) in the model, resulting in zero contributed energy to the system. Therefore there is no impact to overall energy even if MDM firms align with a different MPP.

With basic knowledge of the mobile ecosystem, it is clear that Nokia will align with Symbian and not Microsoft (Nokia being a stakeholder in the Symbian Foundation). This means that Configuration 2 is the more viable out of the two results.

When comparing Configuration 2 (shown in Table 4) to the 2006 visualization of the ecosystem by Basole (2009b), we can see that the results of the model fit the actual structure of the ecosystem quite well. Nokia, Sony Ericsson and LG are in the Symbian alliance, while Motorola and Samsung have greater ties to the Windows Mobile platform. Note that in the visualization, Motorola and Samsung also maintain ties to the Symbian platform However, the algorithm used to generate the visualization assigns meaning to the distance between the MDMs and MPPs, with Motorola and Samsung both being spatially drawn closer to Windows Mobile than Symbian. This indicates a greater "pull" or closeness to the Windows Mobile platform than Symbian for both these companies. Thus, Configuration 2 is a close representation of the actual 2006 alliance structures.

4.1.2 2007

Table 5: Results of Base Landscape Model (2007)

Configuration 1		Configuration 2	
Microsoft	Symbian	Microsoft	Symbian
Nokia	Motorola	Motorola	Nokia
LG	Samsung	Samsung	LG
	Sony Ericsson	Sony Ericsson	

In applying the landscape model to the year 2007, two optimal configurations resulted. Once again, Motorola and Samsung are placed in a rival alliance to Nokia, with Sony Ericsson joining them. LG still maintains ties to Nokia, still the largest MDM in that time period.

As mentioned in 4.1.1, Nokia will partner with Symbian as it is a stakeholder in the Symbian Foundation. Thus, Configuration 2 is the more likely result.
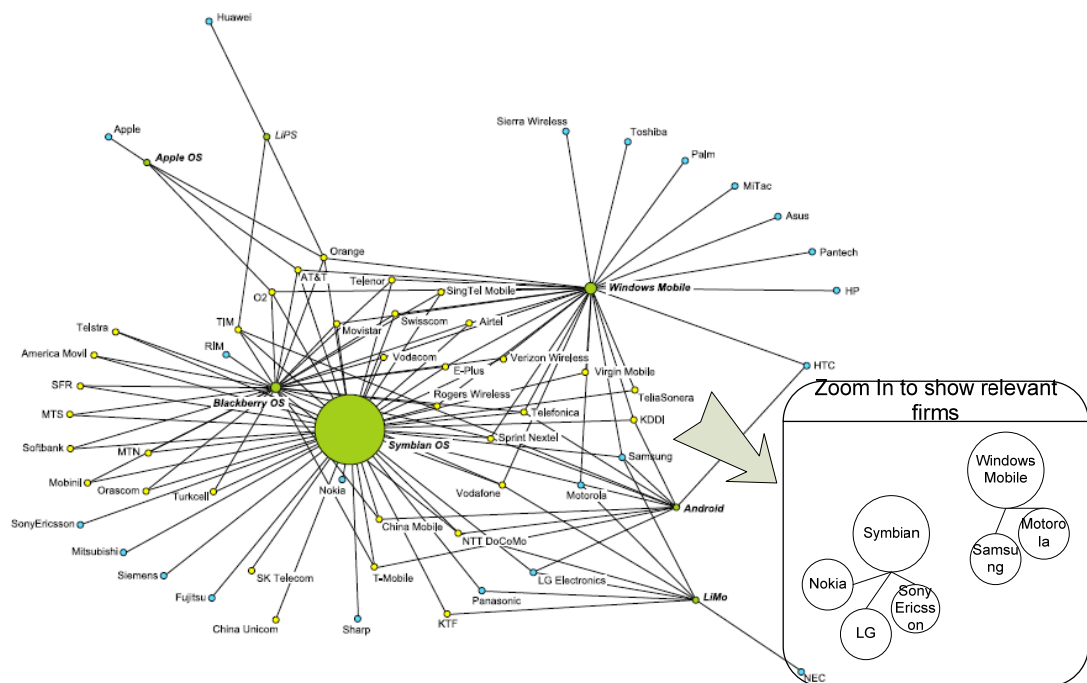
Figure 11: Visualization of Mobile Ecosystem, 2007 (Basole, 2009b)

When comparing this result to Basole's visualization, given in Figure 11, there is a single discrepancy, which is the grouping of Sony Ericsson with Windows Mobile instead of Symbian. Given knowledge of the future loss of market share and revenue for Sony Ericsson that occurs post 2008, it could be said that the real results from the 2007 visualization are in fact not the ideal alliance structures and that Sony Ericsson should

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have made the decision at this stage, to pick the other alliance or hedge bets on multiple

mobile OS platforms as Motorola and Samsung did.

4.1.3　2008

Table 6: Results of Base Landscape Model (2008)

Configuration 1		Configuration 2	
Microsoft	Symbian	Microsoft	Symbian
Nokia	Motorola	Motorola	Nokia
	Samsung	Samsung	
	Sony Ericsson	Sony Ericsson	
	LG	LG	

For 2008, once again, Configuration 2 is a closer representation of the mobile ecosystem

compared to Configuration1. We can see that the alliance structures remain similar to

those seen in 2007. In this year, LG has also defected to the alliance of Samsung, Sony

Ericsson and Motorola.
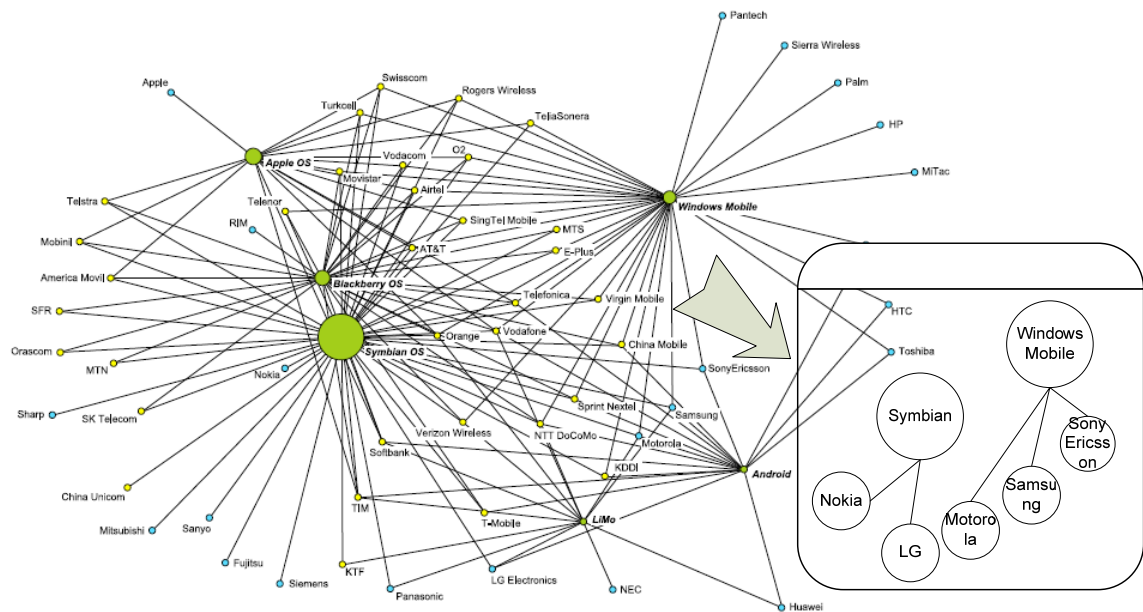
Figure 12: Visualization of Mobile Ecosystem, 2008 (Basole, 2009b)

This alignment is verified by Basole's 2008 network visualization (see Figure 12), where,

although Motorola, Samsung, Sony Ericsson still have ties to the Symbian platform, their

spatial distance from the platform indicates that the ties are not as strong as those to

Windows Mobile. One discrepancy is that LG does not have any ties to Windows Mobile,

rather moving to adopt Android and LiMo while maintaining its Symbian ties. From the

visualization, we can already see the emergence of Android as a competing mobile OS

platform and that these MDMs are already forming ties to it. However, since our 2008

results are solely based on data from 2007, Android does not figure in them since the first commercial version of the operating system was only available in 2008.

4.1.4   2009

Table 7: Results of Base Landscape Model (2009)

Configuration 1			**Configuration 4**		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Nokia	Motorola	Samsung	Samsung	Nokia	Motorola
	Sony Ericsson				Sony Ericsson
	LG				LG
Configuration 2			**Configuration 5**		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Nokia	Samsung	Motorola	Motorola	Samsung	Nokia
		Sony Ericsson	Sony Ericsson		
		LG	LG		
Configuration 3			**Configuration 6**		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Motorola	Nokia	Samsung	Samsung	Motorola	Nokia
Sony Ericsson				Sony Ericsson	
LG				LG	

For 2009, the landscape model returned 6 possible configurations. What is clear is that there are three groups of MDMs that are formed, but because of the lack of positive or negative propensity of any MDM to a single MPP (note that the propensity of all MDMs to MPPs is modeled as 0 or neutral), all the possible permutations of mobile OS platform with the three MDM alliances are returned as optimal alliance structures.

Again, as with the previous year's results, the MDMs create definite alliances, with Motorola, Sony Ericsson and LG partnering with each other, while Nokia and Samsung each choose different MPPs to ally with. The closest representation of the mobile ecosystem is Nokia pairing with Symbian and Motorola, Sony Ericsson and LG joining

the Android platform. This leaves Samsung to partner with Microsoft on the Windows

Mobile platform (Configuration 4).
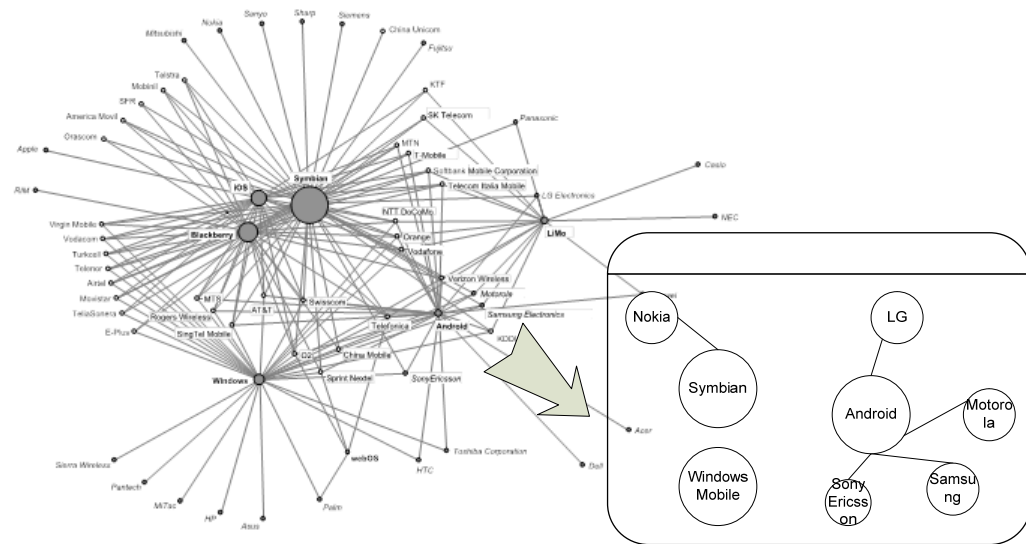
Figure 13: Visualization of Mobilole Ecosystem, 2009 (Basole & Karla, 2011)

Comparing Configuration 4 to the Basole and Karla (2011) visualization above, it can be

seen that Symbian and Nokia do maintain their ties from previous years, while all the

other MDMs choose to ally most closely with the newer Android platform. The one

discrepancy is with Samsung, which the model predicts will choose Windows Mobile but

it also shows a greater preference for Android.

In the context of industry knowledge, the affinity of most MDMs for Android makes

sense for three reasons. Firstly, Android was the first legitimate competitor to the close

iOS mobile OS platform, on which Apple's iPhone is based as it offered many of the

technical capabilities that matched iOS. This was something that Symbian and Windows

Mobile could not offer (Gandhewar & Sheikh, 2010). Secondly, it was licensable and

open source, which leveled the playing field somewhat between smaller and larger firms

by reducing R&D and royalty costs.

The kind of technology disruption that Android provided is not easy to explain with the base landscape model.

4.1.5   2010

Table 8: Results of Base Landscape Model (2010)

Configuration 1			Configuration 4		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Nokia	Motorola	Samsung	Samsung	Nokia	Motorola
LG	Sony Ericsson			LG	Sony Ericsson
ZTE	Huawei			ZTE	Huawei
Configuration 2			**Configuration 5**		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Nokia	Samsung	Motorola	Motorola	Samsung	Nokia
LG		Sony Ericsson	Sony Ericsson		LG
ZTE		Huawei	Huawei		ZTE
Configuration 3			**Configuration 6**		
Microsoft	Symbian	Google	Microsoft	Symbian	Google
Motorola	Nokia	Samsung	Samsung	Motorola	Nokia
Sony Ericsson	LG			Sony Ericsson	LG
Huawei	ZTE			Huawei	ZTE

The above table shows the possible configurations given from the model for 2010. Once

again, the smaller MDMs come together in an alliance while the bigger MDMs tend to

distance themselves from other MDMs.. The three larger MDMs by size, Samsung,

Nokia and Huawei tend to be in separate alliances, with the smaller MDMs such as

Motorola and Sony Ericsson showing a tendency to ally together with Huawei, while LG

and ZTE allying with Nokia. Based on industry knowledge, Configuration 4 is the most

likely to occur.
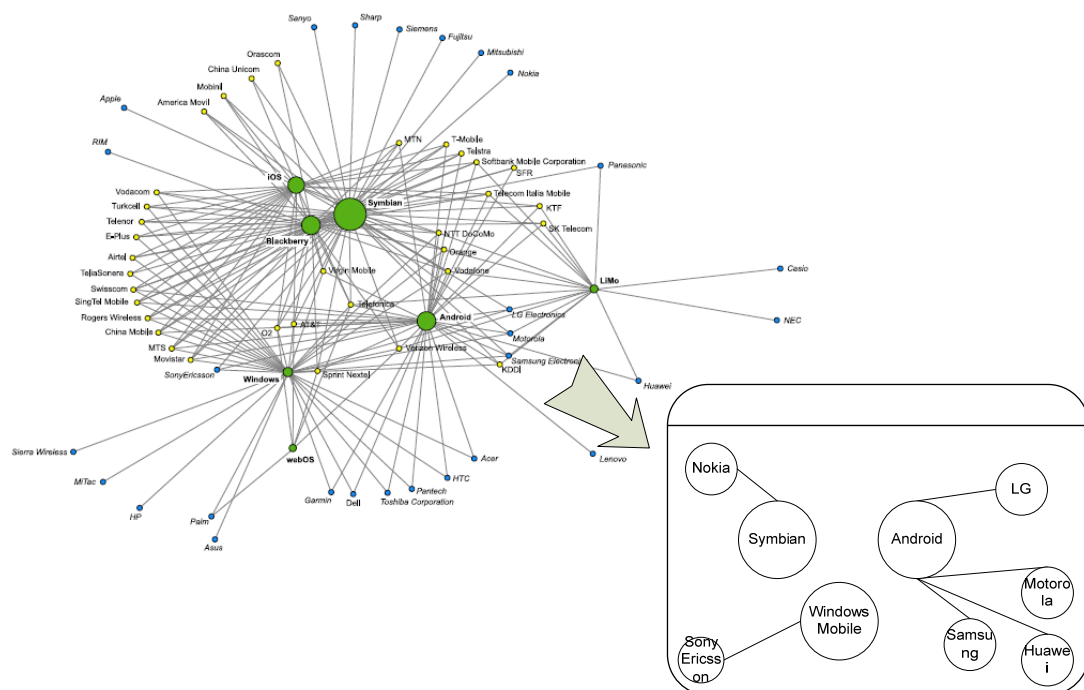
Figure 14: Visualization of Mobile Ecosystem, 2010 (Basole & Karla, 2011)

Basole and Karla's visualizations show that the results of the model are mostly correct,

with Huawei choosing Android as its mobile OS platform of choice, which is the main

choice for Motorola as well. Nokia is tied solely to the Symbian platform. In the

visualization, Sony Ericsson shows a greater preference for Windows Mobile, while

Samsung shows a preference for Android, but is also tied to the Symbian and Windows

Mobile platforms. These are both incorrectly described by the model results. ZTE is not

represented in Basole & Karla's visualization.

5 Chapter: Refining the Mobile Landscape Model

While the results from the previous chapter clearly map to the actual network visualizations over the same time period, the model is lacking in that it does not clearly define mobile OS platform choices made by the MDMs. Therefore all possible combinations of MDM alliances and MPPs are returned as optimal results. In the current modeling of propensity characteristics of the MDMs and MPPs, there are clear negative propensities of MDMs to work together but the neutral MDM-MPP propensities cause the resulting optimal alliance structures given by the model to be ambiguous as to which MPP an MDM would pick. What it does show is the clearly demarcated alliances formed among the various MDMs. This in itself shows some meaningful information to MDMs as to what their strategic stance towards competing MDMs should be. However, in order to gain more value from the model, a more nuanced propensity matrix would have to be devised to show positive or negative propensities of MDMs towards various MPPs.

There may be multiple parameters on which to redefine MDM-MPP propensity. Examples include the technological capability of the mobile OS, the interoperability of the mobile OS software with the current hardware platforms used by the MDM, and the mobile OS used in previous phones released by the MDM.

Although there is research and Internet resources comparing mobile OS platform features fairly comprehensively (Gandhewar & Sheikh, 2010; Wikipedia, 2012; Speckmann, 2008), and there are clear advantages and disadvantages listed for the end user and

mobile application developers, it is not clear if this will result in different propensities for MDMs.

A more relevant measure might be the interoperability and compatibility of mobile OS with the MDMs existing hardware and phone architectures. However, this information is hard to obtain through public data sources and requires in depth knowledge of each MDMs historical hardware choices.

An easier way to measure the same compatibility might be through phone releases per year using a certain mobile OS platform. If a MDM has chosen a certain mobile OS in the past, it provides some indication that the firm had analysed the compatibility of the OS with its hardware. In addition, it indicates that some research and development costs have already been incurred by the MDM to adopt the mobile OS platform, which may increase the preference of the company to continue with the same OS instead of making those capital expenditures in adopting a new mobile OS.

With this reasoning, the data on phone releases per year per manufacturer was obtained and the total phone releases in each year from 2006 to 2010, as well as the releases per mobile OS per manufacturer were tallied. This data was collected from http://www.phonescoop.com, which lists all phone releases by manufacturer. In order to generate a propensity metric, the ratio of phone releases on a certain mobile OS platform to the total phone releases in a year was used.

Note that not all phones released used one of the mobile OS platforms that we considered in our model. In fact, from 2006 to 2009, a significant number of the phones released by MDMs used proprietary operating systems that were developed in house. This must be kept in mind when analyzing the results of the refined model.

The modified propensity values were input into the Propensity matrices and the

calculations were re-iterated in R, according to the equations given below

Propensity$_{MPP-MPP}$ = [1 - (α+β)]
Propensity$_{MPP-MDM}$ = [1 – α] + [Phone Releases on MPP(previous year)/Total Phone Releases]
Propensity$_{MDM-MDM}$ = [1 - (α+β)]

Figure 15: Modified Equations for Propensity

The raw data for phone release per manufacturer is given in the Appendix and also

contain in the Github repository for this research.

5.1   Results – Refined Model

Making the modifications to the propensity metric to include the actual phone releases

from the past year helped narrow down the optimal alliance structure for each year to one

lowest energy solution. The following results were obtained for years 2006 to 2010.

2006
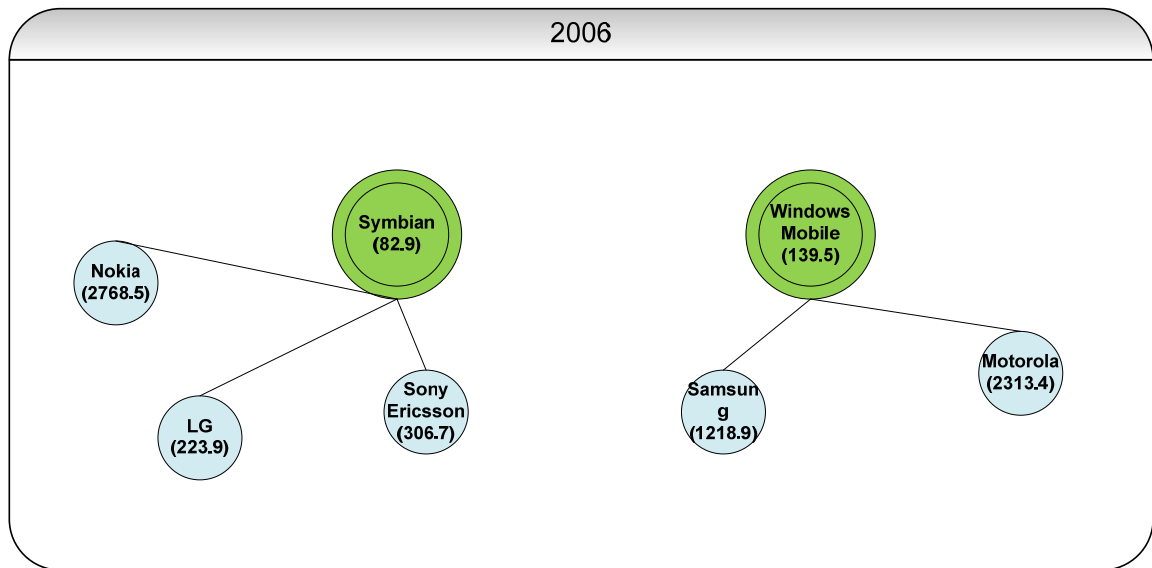
Figure 16: Optimal Result from Refined Landscape Model (2006)

From the above, we can see that the two possibilities that were given by the base model now reduce to the one above, with the new propensity measures. This conclusively returns Configuration 2 as the optimal result, so that the decision to pick 2 over 1 no longer needs to be made based on industry knowledge. The result maps closely to the ties in the visualization, shown in Figure 8 before.

2007
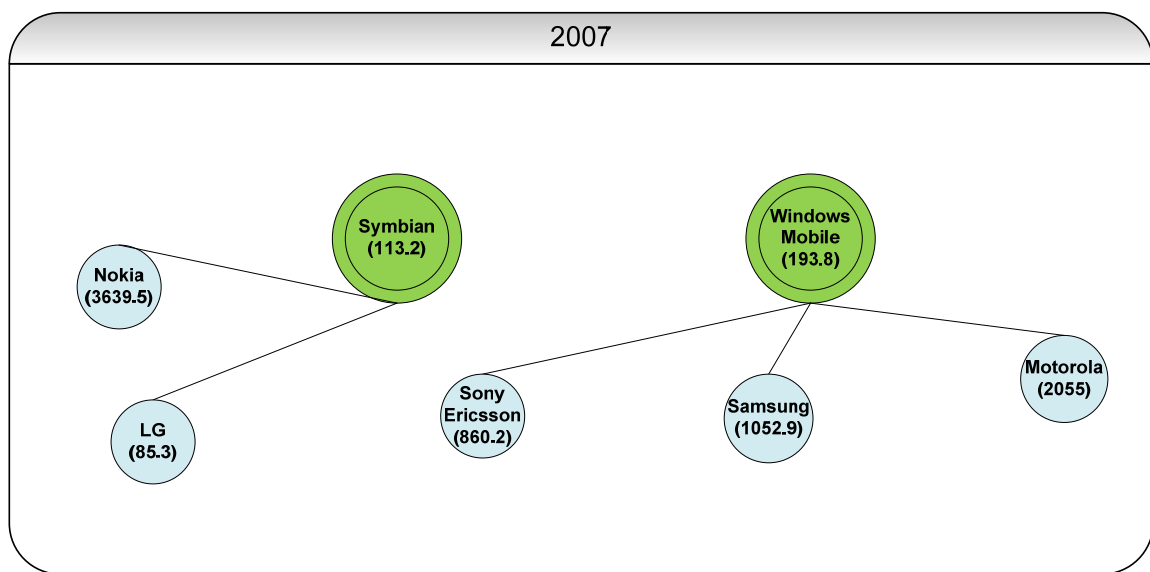
2008
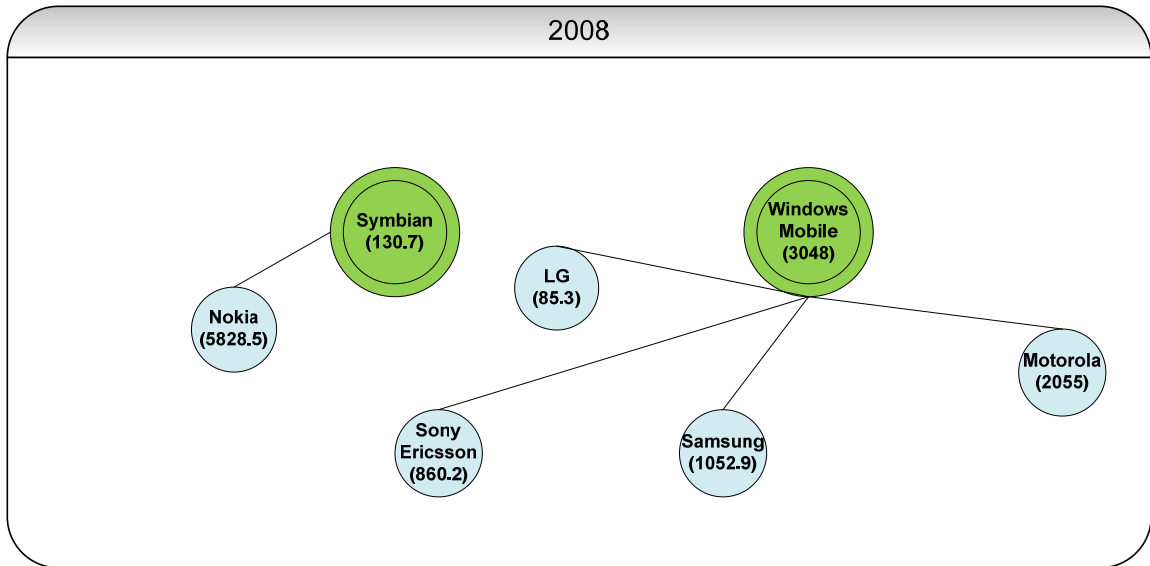
2009
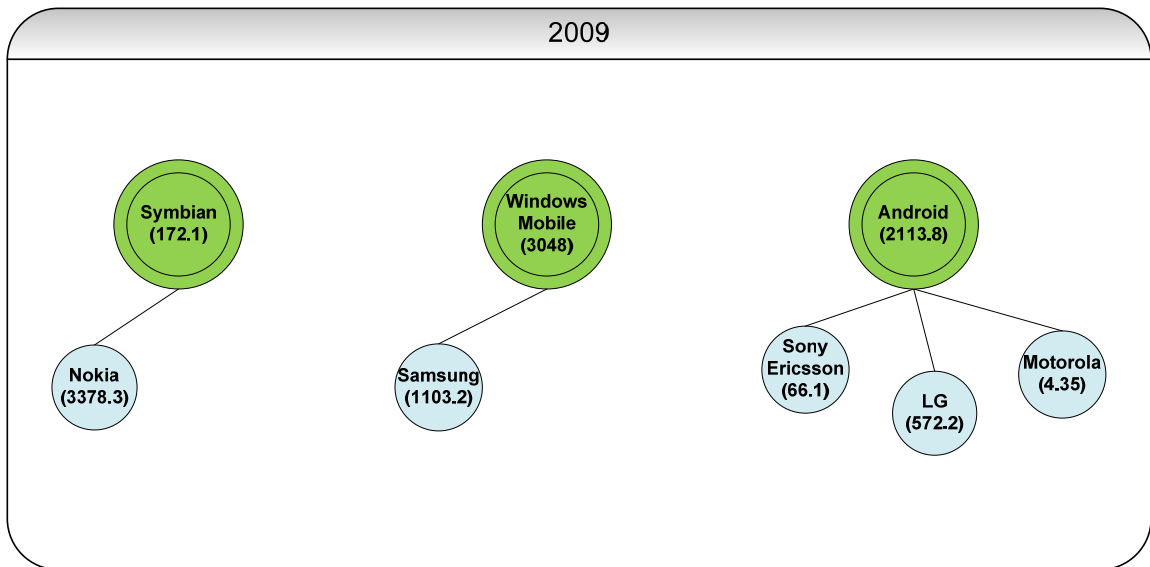
2010
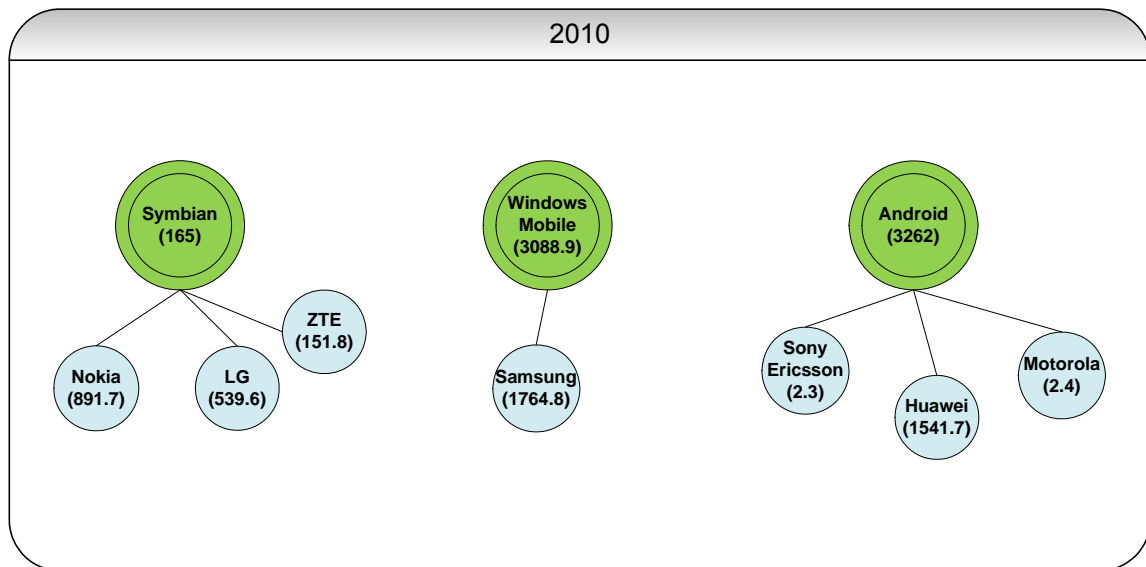
For 2006, 2007 and 2008, the results of the model match the results from the ecosystem visualization very well. In general, the affinity for a certain OS over another is captured in the results of the model as compared to the visualization.

In 2009 and 2010, Samsung is placed in the Windows alliance while Sony Ericsson is placed in the Android alliance, which are not the results reflected in the visualization. A possible explanation for this is that the choice between Windows and Android cannot be made solely on the basis of the size and propensity measures that we have used in the model. There may be other parameters that are outside the scope of the model that could explain the actual alliance structures that occurred. Another explanation for the discrepancy can be given based on the current information that is known about the mobile industry, i.e. Sony Ericsson's loss of market share due to delay in moving from Symbian to Android as their preferred mobile OS platform. Based on the results of the model, Sony Ericsson should have committed to Android much earlier. Thus, we see that perhaps the choices made in reality were not the optimal ones.

Similar explanations can be used to explain why Samsung is shown in the Windows alliance instead of Android. The model is perhaps limited in the parameters that it takes into account when computing optimal alliance configurations. As such, based on other factors (for example, the technological strength of Android over Windows Mobile in 2008), Samsung made the decision to choose Android instead of Windows.

6   Chapter: Discussion of Results

This chapter discusses the main insights gained from this research.

6.1   Basic Metrics are good indicators of alliance structure

Using the mobile landscape model, this research has helped in verifying that the same principles used in the characterization of alliances in World War 2, the Unix wars and the airline industry also apply to the mobile ecosystem. Basic measures such as the market share, revenue, operating profit and phone releases can provide fairly significant insights into the strategic alliances that a MDM should form. This makes landscape theory a very useful tool for any researcher or company strategist looking to get an overall view of the landscape in their respective industry. It has been proven to work in a variety of industries.

Two of the ways in the landscape theory model can be used in the mobile industry is to better understand the decisions made by firms (view of the past) and to input available data at any given point in time and get an indication for the alliances that should be chosen going forward (view of the future). The base model can also be refined to include any parameters of interest to the user, the results of which can be analyzed to determine the effect of that parameter on alliance formation in the mobile industry.

In this way, the mobile landscape model provides a flexible framework which can be modified according to the objectives of the user.

6.2   Base model yielded great insights into the MDM alliances

Just using a very basic model of size and propensity, the model yielded a clear indication of how MDMs would tend to ally with each other. This is very reflective of the actual strategies used by the mobile companies as shown in the Basole visualizations and as such, a great justification for the further use of the landscape model to study mobile ecosystem relationships.

6.3 Refining model yielded very definitive results on the alliance structure

The variation and number of optimal alliance structures was significantly reduced as simple refinements to the model were done. This shows that researchers and management with access to more in depth industry data will be able to quickly find optimal alliance configurations and make quick strategic decisions based on these results.

The simplicity of the model is promising in that it does not require much data to get significant insight into inter-company dynamics and possible alliances.

6.4 Time lag doesn't affect the results of the model

Year after year, we see that with just the data from one year before, a result could be obtained that is fairly close to what the behavior of the firms is in that year. Therefore, there does not seem to be a significant time lag in the actions of the firms. The MDMs and MPPs make very quick moves and propensity can vary significantly from year to year.

In hindsight, this is to be expected given the repreated decriptions of the mobile ecosystem as fast-changing, still converging and fragmented. Firms are still at the stage where they are looking for their optimal alliance and that could mean changing equations between firms in the ecosystem from year to year.

6.5   Model suggests optimal decisions firms should make

Based on certain premises of size and propensity, this model returns the optimal alliance structures that should result. In general, these paths are taken by firms but poor strategic decision making and late realization on the part of firms can leave a gap between what the optimal result would have been and the reality.

For example, the model showed Sony Ericsson switching from the Symbian alliance to Microsoft in the year before (2007) it actually made the move (2008). This shows a delay on Sony Ericsson's part in realizing that it had to re-align with new partners in order to strengthen its position in the ecosystem. Waiting too long to make the move has resulted in depleted market share for the firm as well as the eventual dissolution of the Sony Ericsson joint venture, with Sony buying out Ericsson's share of the business.

6.6   Other insights contained in the results

The model also shows the logic in certain other events that happened over the 5 year observation period.

An example of this is the continued close tie to the Android alliance that Motorola is shown to have since the mobile OS appeared on the market. Given the knowledge that we

have now, that Google was looking to strengthen its position in the ecosystem by acquiring phone manufacturing know-how, it makes sense that it would have picked one of the MDMs tied to its own alliance to work with. Since LG and Sony Ericsson were already part of larger conglomerates, Motorola was an obvious and good choice for Google. The acquisition of Motorola Mobility by Google was announced in August 2011.

6.7   Disruptive innovation is difficult to model

A more disruptive technological disruption is hard to describe with this simple mobile landscape model. Two examples in the history of the mobile industry that cannot adequately be described are:

i) The introduction of the iPhone and the subsequent re-thinking of the smartphone as having a platform-application architecture. Apple provided a platform (iOS) on which is created a rich applications ecosystem, leveraged from its previous success with iTunes for the iPod. This opened the doors for a smarter breed of mobile OS platforms to come about, including Android and Windows Phone.

The emergence of Android as a choice for MDMs is thus hard to model as the paradigm shift towards a platform-app structure of the mobile phone software cannot be described as a simple propensity change.

The only part that could be modeled would be the entry of a large sized firm (Google) as an MPP and thereby the gravitation of the smaller MDMs toward partnering with a larger player to create a sizeable alliance.

ii)   The shutdown of the Symbian OS and the partnership between Nokia and

Microsoft.

Another disruption that is not explained in the current model is the abrupt end of Nokia's

support of the Symbian OS and adoption of Windows Mobile for its subsequent phone

offerings. This switch in mobile platforms is most likely due to i) Symbian not having the

technological capabilities to compete with Android and iOS and ii) Nokia's need to

differentiate from its competitors in the mobile platform it uses. Since Symbian was not

designed to offer the platform-app architecture of Android and iOS, Nokia was ahrd

pressed to choose a platform that did offer that capability. Since its major competitors at

the time (Samsung and Apple) were using Android and iOS respectively, it served

Nokia's strategic interests to use its still significant installed base and resources to

support the third place mobile platform, Windows Mobile, and compete head-to-head

with the other manufacturers.

Since the refined model only takes into account the past platforms used, market share and

profits, it can't account for the significant difference in the technological capability of a

early mobile OS such as Symbian versus a newer OS such as Android.

The ability to account for these discrepancies in the model could be a very useful feature.

For example, looking at the technical capabilities of the OS, the user experience and

satisfaction ratings and business models of the MPPs might have given more insight into

the disruptive changes that occurred within the ecosystem.

7 Chapter: Conclusions

This research aims to explore if landscape theory can be used to indicate how MDMs will strategically pick mobile OS platforms for their future phone offerings.

The development of a landscape model for the mobile industry based on Axelrod & Bennett's (1993) paper and the subsequent results from the model correspond well with the actual landscape of the mobile ecosystem as observed from 2006 to 2010.

Some of the key observations made were:

1) MDMs tend to ally with each other based on their size. Larger MDMs will tend to adopt different mobile OS platforms, presumably in an effort to differentiate themselves as much as possible in the eyes of the consumer and also hold a more central role in a mobile OS ecosystem so as to appropriate as much value from the value network as possible. Smaller MDMs tend to ally with one of the larger MDMs or a group of other smaller MDMs in order to balance the overall size of each alliance so that they are approximately equal.

2) With the introduction of a simple propensity parameter, the number of phone releases per mobile platform per manufacturer, we are able to get results that indicate a preference of a certain OS over another, based on previous usage. For the most part, these match the visualizations of the mobile ecosystem and we can conclude that previous phone releases by a MDM can be indicative of the future mobile OS choices that it will make. In some cases however, the disruption is too drastic to account for

with the limited parameters inputted to the model. For example, the 2011 move from

Symbian to Windows Phone by Nokia is not easy to predict with the current model.

3) Like the phone releases per year parameter, other such factors can be applied to the

base landscape model in order to measure their effect on the actual behavior of firms

in the ecosystem. This could be very useful for a variety of stakeholders to test

hypotheses or to customize the model according to their known key performance

metrics.

7.1   Limitations

While being a useful way in which to view and predict strategic ecosystem alliances, the

landscape model, has a number of limitations that should not be disregarded.

1) One of the most important limitations of the model is the inability to describe various

external factors that have an influence on how the firms in the system choose to ally

with each other. In the research method, we described the reductions in scope

performed in order to make a meaningful model.

Firstly, only mobile OS platforms that can be licensed are considered in the model, as

only those can be used by MDMs in their handsets. This precludes the Apple (iOS) or

Research In Motion (Blackberry OS) from being considered in this study, although

they both hold significant market shares in the time period being considered (2006-

2010). As such the effect of these mobile OS platform on the tactics employed by

MDMs in the model are not measured. As an example, the introduction of Apple's

iOS in their iPhone handset clearly marked the paradigm shift to the consideration of

mobile OSs as application platforms rather than purely software platforms. This

fundamental change in approach resulted in Google responding with the introduction

of the Android platform, which was an open and licensed version of the iOS platform. Thus, the introduction of Android into the model in 2009 is a response more to the external effect of Apple's iOS rather than a direct competitive attempt to challenge Symbian or Windows Mobile. As such, there was wholesale adoption of the platform by all MDMs (except for Nokia), which is not described by the landscape model as it is. This is a key example of how external factors affect the decisions made by MDMs and MPPs that were considered.

Secondly, another factor to consider is that not all phone releases by the MDMs in the time period 2006-2010 can be classified to be using one of the 3 MPPs considered. A great number of the phones released by all the MDMs use proprietary, pre-smartphone mobile operating systems. The sales of these low to mid-tier phones are aimed as differentiated market offerings in price sensitive markets, typically in the developing world. Considering that the size metric for MDMs consists of market share and operating profit, we have to consider that both of these measures include both smartphone shares and sales as well the sales of these other phones. Thus, a MDMs success in the low to mid tier market may effectively subsidize their smartphone releases, thus masking their true success in the smartphone market.

2) Another limitation of how the research scope is defined is that very small, niche MDMs (with less than 1 % of market share individually), are not considered in the model. Although these MDMs form less than 1 % of the market individually, they can hold as much as 25% of the market collectively. Therefore, the competitive forces

that arise on the larger MDMs due to these smaller firms can be significant, especially in the low to mid tier phone market. This may not affect those MDMs that are focused on the high end phone (smartphone) market, but for those MDMs that have low-, mid- and high-end offerings, this is a force that is not measured in the landscape model currently.

3) A third limitation of the current model is that assigns at most one MPP per MDM, as the optimal platform and alliance for that MDM. In reality, visualizations of the ecosystem (Basole & Karla, 2011) and market research reports (Vision Mobile) show that some MDMs tend to hedge their bets by launching a few phones with different mobile OS platforms every year so as to be able to have the capability to adopt any of them as their platform of choice, if ever that decision has to be made in the future.

7.2   Suggestions for Future Research

The following suggestions are made for future research:

1) A variety of different propensity parameters can be added to the model in order to measure their efficacy in predicting alliances of MDMs and MPPs. One suggestion of a parameter to be measured is the technological capability of each mobile OS platform and whether the platform is open or not.

2) A larger number of members of the actual mobile ecosystem can be included in the landscape model to make it an analytical tool for a greater number of players.

Appendices

Appendix A   Landscape Theory – A Primer

This is a detailed explanation of landscape theory and how calculations are done.

A.1   Landscape Theory of Aggregation

Aggregation refers to the organization of elements of a system into patterns that tend to put highly compatible elements together and less compatible elements apart (Axelrod & Bennett, 1993). Landscape theory predicts how aggregation will lead to alignments among actors.

For a set of n actors in any application of the theory, three constructs, size, propensity and configuration are most important. The size of an actor, $s_i > 0$, is a reflection of the importance of that actor to others. Size can be measured by demographic, industrial and economic factors, or any combination of these, depending on what is important in a particular application.

Another key premise is that 2 actors have a certain propensity to work together. That propensity will be positive if 2 actors get along well and negative if they don't. In the context of businesses forming alliances, strong competitors will have increased negative propensity to work together. Therefore propensity is a measure of how willing 2 firms are to be in the same alliance. Landscape theory assumes that propensity is a symmetric property of 2 actors in a system i.e. actor B will have the same propensity toward actor A that A has towards B.

A configuration is a partition of the actors ina system into one of two groups. This can also be called an alliance structure. For all possible alliance structures, a distance matrix is created, which describes how the actors are arranged in 2 groups. For example, for 4 actors, A,B,C and D, two different configurations are shown below, with their corresponding distance matrices.

As mentioned in section 3.3.1 above, the following definition of distance is used to decide that value of distance per pair of actors.

$$\text{Distance, } D_{ij} = \begin{cases} 0, \text{ if } i \text{ and } j \text{ are in the same alliance} \\ 1, \text{ if } i \text{ and } j \text{ are not in the same alliance} \end{cases}$$
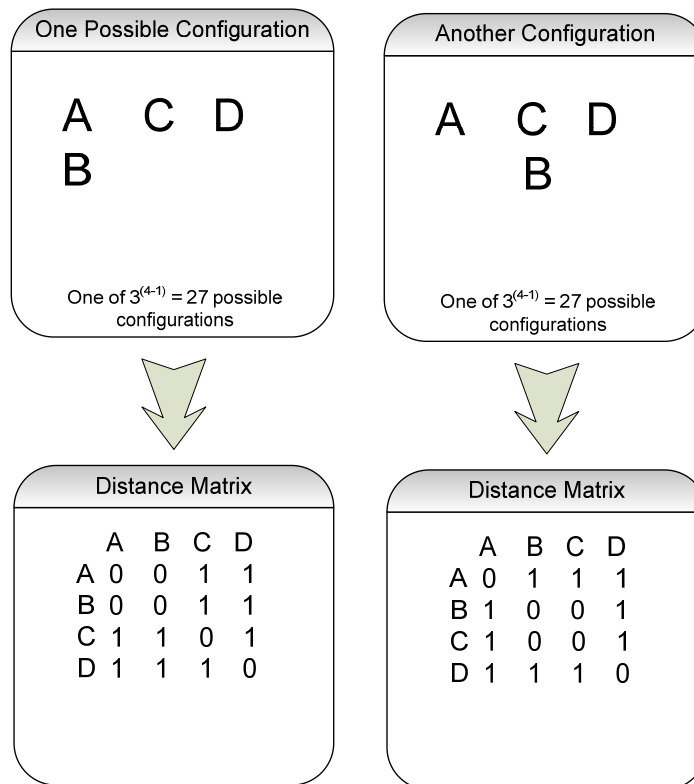
Figure 17: Configurations and corresponding Distance matrices

By expressing size, propensity and distance in matrix form, it is possible calculate the utility or payoff function for each actor as well as the overall "energy" of each configuration.

The utility of actor A is the total value of the size of all other actors multiplied by their propensity and distance from A. The terms in this sum are non-zero only if the distance between A and another firm is 1 i.e. they are in different alliances. Ideally, an actor would want all the actors with which it has a negative propensity to be in other alliances. Therefore a larger negative value of utility shows that the actor has the least amount of "frustration", as its competitors are in other alliances.

Since we must consider the frustrations of all the actors in the system, we use the weighted sum of the frustrations to define the energy of the system. By weighting the frustration of each actor by its size, we are giving more importance to larger sized actors (i.e. those with more clout) achieving the lowest frustration for themselves. The configuration or configurations that yield the lowest energy value are the ones that the landscape model defines as the most optimal alliance structures. These alliances result in the optimization of the frustration that each actor has to face. Axelrod and Bennett (1993) describe the energy values as a landscape of possible alliance configurations, of which the occurrences of the lowest energy value are local optimas or local minimas in the landscape, hence the name landscape theory.

The theory is supported by the results of two cases: the alignment of seventeen European nations in the Second World War and membership in competing alliances of nine computer companies to set standards for Unix computer operating systems

A.2   Matrix Mathematics

In order to carry out the calculations for the energy, we need an easy way to manipulate the size, propensity and distance values for an application of the landscape model. In order to do this, we describe the size, propensity and distance as matrices.

Size is a *1xn* matrix, where n represents the number of actors being considered. Each column contains the size value for 1 actor in the system.

Propensity is a *nxn* matrix, which shows the pairwise propensities between n actors. The columns describe the firms in the same order as in the size matrix.

Distance is a *nxn* matrix, which shows, for each configuration, what the distance between 2 actors is. The columns describe the firms in the same order as in the size matrix.

An example of how the matrices look is given below.

Size Matrix			
A	B	C	D
28	14.3	25.4	114

Propensity Matrix				
	A	B	C	D
A	0	0	-1	-1
B	0	0	1	0
C	-1	1	0	-1
D	-1	0	-1	0

Distance Matrix				
	A	B	C	D
A	0	0	1	1
B	0	0	1	1
C	1	1	0	1
D	1	1	1	0

This is based on the configuration where A and B are in Group 1, C in Group 2, and D in Group 3 (shown in Figure 17)
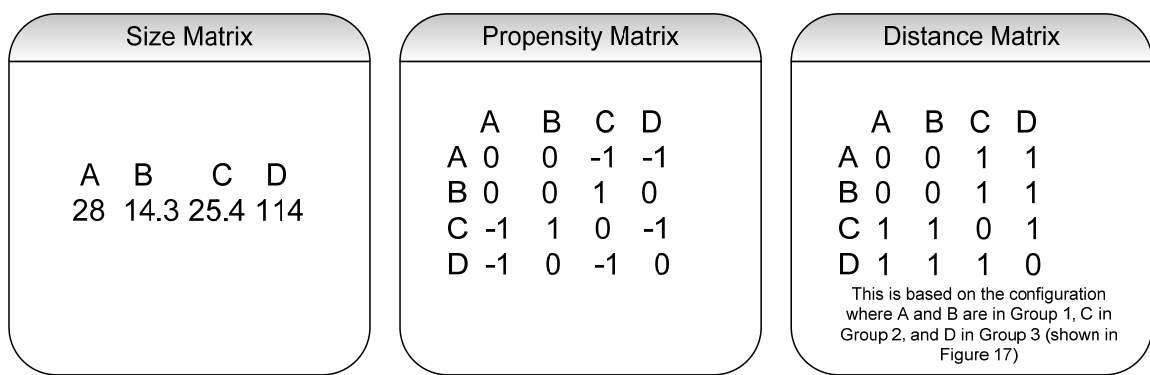
Figure 18: Example of Size, Propensity and Distance Matrices

To generate the Utility per actor, we calculate the Hadamard Product (element wise multiplication) of the Propensity and Distance matrices. This returns another nxn matrix. This matrix, multiplied by the Size matrix, returns the Utility function for each actor.

Size Matrix

	A	B	C	D
	28	14.3	25.4	114

Hadamard Product (Propensity x Distance)

	A	B	C	D
A	0	0	-1	-1
B	0	0	1	0
C	-1	1	0	-1
D	-1	0	-1	0

Utility Matrix

	A	B	C	D
	-139.4	25.4	-127.7	-53.4
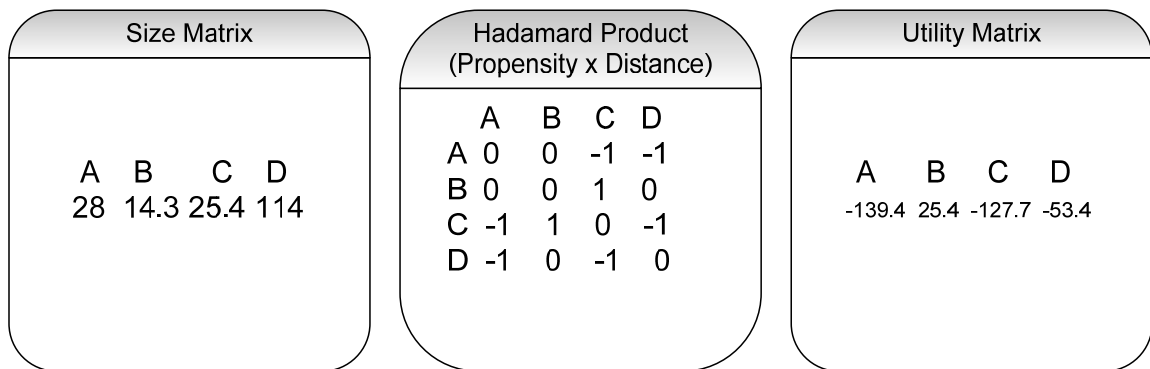
Figure 19: Calculation of the Utility values from Actors in the System

The Utility matrix, multiplied again by the Size matrix, gives the energy value for this particular configuration.

Size Matrix

	A	B	C	D
	28	14.3	25.4	114

Utility Matrix

	A	B	C	D
	-139.4	25.4	-127.7	-53.4

Energy Value

-12871.2
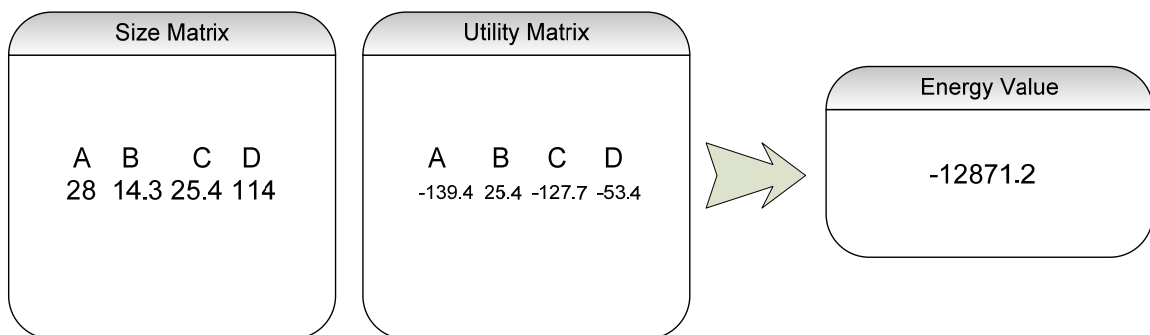
Figure 20: Calculation of Energy for a particular Configuration

Once the energy values for all possible configurations are calculated, the configuration that returns the lowest energy value is determined as the optimal alliance structure for firms A, B,C and D to adopt.

Appendix B Data Collection and Processing

This appendix contains the data used to calculate the size and propensity values that were used in the landscape model. It also describes how the data was used by the R scripts to generate the results.

B.1　　Raw Data

The raw data collected is displayed in the tables below. All data is obtained from publicly available sources on the Internet. For data that was not recent, some use of the http://wayback.archive.org website was made.

<Spreadsheet containing the following metrics by year>

Market Shares

Revenue

Operating Profits

Phones releases by manufacturer and mobile OS

B.2 Size and Propensities

The size and propensity calculations for the base landscape model were made on the basis

of the equations given below:

$$Size_{MPP} = \tfrac{1}{2}(\text{Market Share}) + \tfrac{1}{2}(\text{Revenue})$$
$$Size_{MDM} = \tfrac{1}{2}(\text{Market Share}) + \tfrac{1}{2}(\text{Operating Profit})$$

$$Propensity_{MPP\text{-}MPP} = [1 - (\alpha+\beta)]$$
$$Propensity_{MPP\text{-}MDM} = [1 - \alpha]$$
$$Propensity_{MDM\text{-}MDM} = [1 - (\alpha+\beta)]$$

For the refined model, the propensity equation for MPPs and MDMs was modified as

follows:

$$Propensity_{MPP\text{-}MDM} = [1 - \alpha] + [(\text{Phone Releases on MPP/Total Phone Releases})]$$

As defined in Axelrod et. al. (1995), for all the equations above, $\alpha = 1$ and $\beta = 1$.

Below are the Size and Propensity tables for 2006 to 2010.

2006

Size:

2006	Revenue (millions USD)	Market Share	Operating Profit (millions USD)	**Size**
Microsoft	262	17		**139.5**
Symbian	114.8	51		**82.9**
Nokia		34.9	5502	**2768.45**
Motorola		21.8	4605	**2313.4**
Samsung		11.7	2426	**1218.85**
Sony Ericsson		6.3	607	**306.65**
LG		6.8	441	**223.9**

Propensity (Base):

2006	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0	0	0	0
Symbian	-1	0	0	0	0	0	0
Nokia	0	0	0	-1	-1	-1	-1
Motorola	0	0	-1	0	-1	-1	-1
Samsung	0	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

Propensity (Refined):

2006	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0.07	0.06	0	0
Symbian	-1	0	0.1	0	0.02	0	0
Nokia	0	0.1	0	-1	-1	-1	-1
Motorola	0.07	0	-1	0	-1	-1	-1
Samsung	0.06	0.02	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

2007

Size:

2007	Revenue	Market Share	Operating Profit	Size
Microsoft	377	10.6		**193.8**
Symbian	165.2	61.2		**113.2**
Nokia		34.9	7244	**3639.45**
Motorola		18	4092	**2055**
Samsung		11.86	2094	**1052.93**
Sony Ericsson		7.49	1713	**860.245**
LG		6.67	164	**85.335**

Propensity (Base):

2007	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0	0	0	0
Symbian	-1	0	0	0	0	0	0
Nokia	0	0	0	-1	-1	-1	-1
Motorola	0	0	-1	0	-1	-1	-1
Samsung	0	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

Propensity (Refined):

2007	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0	0.05	0	0
Symbian	-1	0	0.3	0	0	0	0
Nokia	0	0.3	0	-1	-1	-1	-1
Motorola	0	0	-1	0	-1	-1	-1
Samsung	0.05	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

2008

Size:

2008	Rev	Market Share	Operating Profit	**Size**
Microsoft	6083	13		**3048**
Symbian	194.3	67		**130.65**
Nokia		38.98	11618	**5828.49**
Motorola		14.2	0	**7.1**
Samsung		13.4	2954	**1483.7**
Sony Ericsson		8.8	2290	**1149.4**
LG		6.8	1001	**503.9**

Propensity (Base):

	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0	0	0	0
Symbian	-1	0	0	0	0	0	0
Nokia	0	0	0	-1	-1	-1	-1
Motorola	0	0	-1	0	-1	-1	-1
Samsung	0	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

Propensity (Refined):

2008	MS	Symbian	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	0	0.07	0.07	0	0
Symbian	-1	0	0.46	0	0	0	0
Nokia	0	0.46	0	-1	-1	-1	-1
Motorola	0.07	0	-1	0	-1	-1	-1
Samsung	0.07	0	-1	-1	0	-1	-1
Sony E	0	0	-1	-1	-1	0	-1
LG	0	0	-1	-1	-1	-1	0

2009

Size:

2009	Rev	Market Share	Operating Profit	Size
Microsoft	8140	11.8		**4075.9**
Symbian	291.7	52.4		**172.05**
Nokia		38.6	6718	**3378.3**
Motorola		8.7	0	**4.35**
Samsung		16.3	2190	**1103.15**
Sony Ericsson		7.6	124.5	**66.05**
LG		8.4	1136	**572.2**
Google	4227	0.5		**2113.75**

Propensity (Base):

2009	MS	Symbian	Google	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	-1	0	0	0	0	0
Symbian	-1	0	-1	0	0	0	0	0
Google	-1	-1	0	0	0	0	0	0
Nokia	0	0	0	0	-1	-1	-1	-1
Motorola	0	0	0	-1	0	-1	-1	-1
Samsung	0	0	0	-1	-1	0	-1	-1
Sony E	0	0	0	-1	-1	-1	0	-1
LG	0	0	0	-1	-1	-1	-1	0

Propensity (Refined):

2009	MS	Symbian	Google	Nokia	Motorola	Samsung	Sony E	LG
MS	0	-1	-1	0	0	0.09	0	0.05
Symbian	-1	0	-1	0.48	0	0	0	0
Google	-1	-1	0	0	0	0	0	0
Nokia	0	0.48	0	0	-1	-1	-1	-1
Motorola	0	0	0	-1	0	-1	-1	-1
Samsung	0.09	0	0	-1	-1	0	-1	-1
Sony E	0	0	0	-1	-1	-1	0	-1
LG	0.05	0	0	-1	-1	-1	-1	0

2010

Size:

2010	Rev	Market Share	Operating Profit	Size
Microsoft	7753	8.7		**3880.9**
Symbian	283.1	46.9		**165**
Nokia		36.4	1747	**891.7**
Motorola		4.8	0	**2.4**
Samsung		19.5	3510	**1764.8**
Sony Ericsson		4.5	0	**2.3**
LG		10.1	1069	**539.6**
ZTE		1.3	302.3	**151.8**
Huawei		1.0	3082.3	**1541.7**
Google	6520	3.9		**3262**

Propensity (Base):

	MS	Symbian	Google	Nokia	Motorola	Samsung	Sony E	LG	ZTE	Huawei
MS	0	-1	-1	0	0	0	0	0	0	0
Symbian	-1	0	-1	0	0	0	0	0	0	0
Google	-1	-1	0	0	0	0	0	0	0	0
Nokia	0	0	0	0	-1	-1	-1	-1	-1	-1
Motorola	0	0	0	-1	0	-1	-1	-1	-1	-1
Samsung	0	0	0	-1	-1	0	-1	-1	-1	-1
Sony E	0	0	0	-1	-1	-1	0	-1	-1	-1
LG	0	0	0	-1	-1	-1	-1	0	-1	-1
ZTE	0	0	0	-1	-1	-1	-1	-1	0	-1
Huawei	0	0	0	-1	-1	-1-	-1	-1	-1	0

Propensity (Refined):

2010	MS	Symbian	Google	Nokia	Motorola	Samsung	Sony E	LG	ZTE	Huawei
MS	0	-1	-1	0	0	0.09	0	0.05	0	0
Symbian	-1	0	-1	0.44	0	0	0.25	0	0	0
Google	-1	-1	0	0	0.25	0.05	0.25	0	0	0
Nokia	0	0.44	0	0	-1	-1	-1	-1	-1	-1
Motorola	0	0	0.25	-1	0	-1	-1	-1	-1	-1
Samsung	0.09	0	0.05	-1	-1	0	-1	-1	-1	-1
Sony E	0	0	0.25	-1	-1	-1	0	-1	-1	-1
LG	0.05	0	0	-1	-1	-1	-1	0	-1	-1
ZTE	0	0	0	-1	-1	-1	-1	-1	0	-1
Huawei	0	0	0	-1	-1	-1	-1	-1	-1	0

B.3   Data Processing in R

The Size and Propensity information was captured above was entered into Comma

Separated Values (CSV) files, labeled by year. An example of the 2006 files is shown

below. All files and scripts discussed below are available on GitHub in the repository:

shrutisatsangi/mobile_landscape

Size_2006.csv file

```
Microsoft,Symbian,Nokia, Motorola, Samsung, Sony Ericsson, LG
139.5,82.9,2768.45,2313.4,1218.85,306.65,223.9
```


Propensities_base_2006.csv file

```
Microsoft,Symbian,Nokia,Motorola,Samsung, Sony Ericsson, LG
0,-2,0,0.07,0.06,0,0
-2,0,0.1,0,0.02,0,0
0,0.1,0,-1,-1,-1,-1
0.07,0,-1,0,-1,-1,-1
0.06,0.02,-1,-1,0,-1,-1
0,0,-1,-1,-1,0,-1
0,0,-1,-1,-1,-1,0
```


The CSV files were accessed via the R script to generate Size and Propensity matrices in

R. The Distance matrix was generated and these three matrices were used to calculate the

Utility value for each company and Energy of the system. This was done for each

possible combination of companies possible, given a 2 alliance or 3 alliance system.

R script for 2 alliance energy calculation:

```
#generate all combinations of d
# n represents the number of firms in the system
n <- 7
# b represents the base number
b <- 2
#Load Size and Propensity matrices
# Size
S <- read.csv(file="size_2007.csv", head=TRUE, sep=",")
print(S)
# Propensities
P <- read.csv(file="propensities_2007.csv", head=TRUE, sep=",")
print(P)

#Generate a matrix to store Energy values
E <- matrix(numeric(0),1,b^(n-1))

# Generate the Distance(D) matrices and perform Utility Calculation for
each D
for (k in 0:b^(n-1))
{
  d <- digitsBase(k, base=b, n)

  #Generate the D matrix out of a d vector
  #sample d vector for testing: d <- c(1,2,1,1,1,1)
  #generate empty matrix D
  D <- matrix(numeric(0), n,n)
  #Populate D
  for(i in 1:n)
  {
      for (j in 1:n)
      {
            if (i==1)
            {
                  if (d[j] == d[i]){D[i,j] <- 0} else {D[i,j] <- 1}
            }
            else
            {
                  if (D[1,i]== D[1,j]) {D[i,j] <- 0} else {D[i,j] <- 1}
            }
      }
  }
  #print(k)
  #print("d =")
  #print(d)
  #print("D =")
  #print(D)

  # Perform calculation of the Utility based on the new D just
generated
  # Hadamard Product of P and D (each propensity multiplied into
distance)
  I1 <- P*D
  #convert I1 and S to matrices to do multiplication
  I2 <- as.matrix(I1)
```

```
  S2 <- as.matrix(S)
  # Multiply S by I to get Utility functions for all actors
  I3 <- S2 %*% I2
  U <- I3 * S
  # Sum the Utilities to get Energy value for this combination
  E[k] <- sum(U)
  #cat("k= ", k, " Energy= ", E[k], "\n")
}
d1 <- which( E == min(E))
cat("Min E is = ", min(E), "occurring at ", d1 , "\n")
cat("Combinations are:\n")
for (t in 1:length(d1))
{
cat(t, ": ", digitsBase(d1[t], base=b, n), "\n")
}
```

R script for 3 alliance energy calculation:

```
#generate all combinations of d
# n represents the number of firms in the system
n <- 10
# b represents the base number
b <- 3
#Load Size and Propensity matrices
# Size
S <- read.csv(file="size_2010.csv", head=TRUE, sep=",")
print(S)
# Propensities
P <- read.csv(file="propensities_2010_1.csv", head=TRUE, sep=",")
print(P)

#Generate a matrix to store Energy values
E <- matrix(numeric(0),1,b^(n-1))

# Generate the Distance(D) matrices and perform Utility Calculation for
each D
for (k in 0:b^(n-1))
{
  d <- digitsBase(k, base=b, n)

  #Generate the D matrix out of a d vector
  #sample d vector for testing:
  #d <- c(0,1,0,0,0,2,0,2)
  #generate empty matrix D
  D <- matrix(numeric(0), n,n)
  #Populate D
  for(i in 1:n)
  {
      for (j in 1:n)
      {
            if (d[j] == d[i]){D[i,j] <- 0} else {D[i,j] <- 1}
      }

  }
```

```
  #print(k)
  #print("d =")
  #print(d)
  #print("D =")
  #print(D)

  # Perform calculation of the Utility based on the new D just
generated
  # Hadamard Product of P and D (each propensity multiplied into
distance)
  I1 <- P*D
  #convert I1 and S to matrices to do multiplication
  I2 <- as.matrix(I1)
  S2 <- as.matrix(S)
  # Multiply S by I to get Utility functions for all actors
  I3 <- S2 %*% I2
  U <- I3 * S
  # Sum the Utilities to get Energy value for this combination
  E[k] <- sum(U)
  #cat("k= ", k, " Energy= ", E[k], "\n")
}
d1 <- which( E == min(E))
cat("Min E is = ", min(E), "occurring at ", d1 , "\n")
cat("Combinations are:\n")
for (t in 1:length(d1))
{
cat(t, ": ", digitsBase(d1[t], base=b, n), "\n")
}
#print(E)
```

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