An Assessment of Mobile OS-Centric Ecosystems

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Abstract

The evolution of software ecosystems is the result of the popularity and adoption of common architectural development for multiple product development and represents a significant shift in traditional software development style and process methodology. Currently several organizations are in practice with this new process model that embraces business as one of its central factors and have thrived as a result. There can be no doubt that the development of software ecosystems have caused major players in the software industry to rethink their operating practices and engage with third parties, opening their platforms to external entities to attain business objectives. In this paper we examine four of the organizations that are at the forefront of software ecosystem adoption, specifically for mobile devices and explore their business development models. This investigation explores and compares their business process models in terms of how they engage with the external players in order to develop and distribute software and services in this changing marketplace. The study found some commonalities as well as some salient differences in their business processes and presents an assessment of the health of each mobile OS-centric ecosystem. We conclude that this study will help in further aiding understanding of the business process role in this area of ecosystem software.

Keywords: Ecosystems, Software development, Software business model, Mobile devices, Mobile operating systems

1   Introduction

The domain of software ecosystems is still in its infancy and as a result a number of definitions of what exactly constitutes an ecosystem exist. In its most fundamental sense, a software ecosystem (SECO) is a system within which the traditional walls between development entities have been broken down allowing collaboration and interoperability between parties. The pioneers of SECOs seem to agree that the essential elements of such SECOs are an informal network through which independent entities collaborate to produce software and services for a common market. Bosch [5] focuses on the organizational aspects of SECOs and the relationship between these corporations in providing software and services, while Kittlaus and Clough [20] are narrower in their definition, stating that a SECO is an informal network of legally independent units that have a positive influence on the economic success of a software product. Jansen *et al* [18] define a SECO as a set of actors functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. They further note that these relationships are commonly founded on a common technological architecture or market space and operate through the exchange of information, resources and artifacts [19]. We suggest that these definitions are all in fact accurate and rather than being contradictory, they demonstrate the growing maturity in understanding of SECOs and their rapid expansion over the past number of years. As a result we refine the definition of a software ecosystem as, a cluster of actors (individuals or organizations) employed in the development of services or software for a common market and sharing a common technological framework. Bosch also presents a Software Ecosystem Taxonomy, examining the development of SECO across three broad platforms, desktop, web and mobile [5]. The focus of this study is on the mobile deployment of software ecosystems and as a result we class this paper as being mobile OS-centric. In this paper we examine the use of software ecosystems by four software industry leaders in the mobile OS-centric market: Apple, Google, BlackBerry and Nokia, and examine the business model which has been employed by each when embracing this new style of software development and marketing.

1.1   Transition to Ecosystems

We would argue that the development of SECOs is a logical next step for such software development organizations following on from the adoption of the Software Product Lines approach in software architecture design. Software architecture is the structure of the components in a program or system, their interrelationships, and the principles and guidelines governing their design and evolution [4], [13]. Software architecture has a long history of evolution and in this modern age this transformation lead to the development of software product line architecture, where the concern is not single product development but rather the on multiple product development through a shared architecture. Software product line is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment and are developed from a common set of core assets in a prescribed way [7], [22]. This approach has gained increased attention from software development organizations because of the promising benefits in cost reduction, quality improvements and reduced delivery schedule. Clement et al. [8] report that software product line engineering is a growing software engineering sub-discipline, and many organizations, including Philips®, Hewlett-Packard®, Nokia®, Raytheon®, and Cummins®, are using it to achieve extraordinary gains in productivity, time to market, and product quality. The economic potentials of software product lines have been recognized in software industry [6], [27] and these advantages are central to success in today's competitive environment where organizations are continuously adopting innovations in major areas of business operations, such as technology, administration, and production processes. The concept of SECO has its roots in the concepts of common architecture development and social networking and is a further transitional, evolutional and innovative transformation in software architecture design [5], [21].

1.2   Re-engineering Business Processes for SECO

Today, all technology businesses are experiencing increased competition and customers' expectations continuously rise as technology advances at an unprecedented rate of growth, particularly in the mobile market. The rapid and continual changes common in the current business environment not only affect business itself but also have a profound impact on production. Software is perhaps the most crucial piece of a business entity in this modern marketplace, where important decisions need to be made immediately to satisfy user demand. Organizations that fail to respond appropriately do not survive. The key to success lies in the continuous monitoring of customers and competitors and in making improvement plans based on observations and measurements. In order to respond under these conditions it is essential that organizations have a robust and efficient business process in place. Davenport [10] describes a business process as a structured set of activities designed to produce a specific outcome. Aguilar-Sav'en [1] asserts that a business process is the combination of a set of activities within a structured enterprise. The business process of a SECO identifies order of entry to the market, market orientation and relationship management as crucial in successfully launching and managing SECO. The benefits of being the first in the market have long been recognized in the business sector; pioneers often gain a sustainable competitive advantage over followers, because, initially, they are the only solution-providers in a particular market segment [15]. It becomes very difficult for successors to gain a share of the market segment, especially in the case of software, where migration to other software is relatively uncommon. The timing for technology-based products entering the market is even more critical for the profitability and competitive position of an organization. The SECO provides an opportunity to develop

Piers R.J. Campbell
Faheem Ahmed

multiple products from a common architecture rapidly using a community of developers, which increases the possibilities of being first and subsequently increases profitability. The concept of market orientation provides an advantage over competitors by identifying what customers' want, and then offering products that are equivalent and potentially superior to those offered by competitors. Market orientation deals with the acquisition, sharing, interpretation, and use of information about customers and competitors, both of which have a significant impact on the performance of the business. An SECO has the tendency to develop applications that cover a wide range of operations and uses, thus covering a larger domain when compared to traditional organizational offerings. For example, in case of the Apple iPhone, a large variety of applications are developed covering the areas of games, graphics, scientific, educational etc. The effective management of the buyer–seller relationship is highly critical for successful businesses. Business success is highly dependent on the extent to which customers are satisfied with an organization's product and services, as well as how they win the loyalty of customers by improving their relationship management. Relationship management plays a significant role in successful SECO development. The customers are satisfied when the application running on their machines are covering what they want. As a wide range of applications are produced through the SECO platform which results in the higher possibility of satisfaction from customers' perspectives about what they require or need. Moreover the customers also have the opportunity to join the network of developers, creating applications by themselves, which can be used for personal use or commercial sale.

1.3   Software Ecosystems

It is within these conditions that the mobile application store has evolved. Lead by the pioneer in the market, Apple, this has become one of the leading areas for SECO development as vendors attempt to follow Apple into the market and gain a foothold. In this paper we present an investigation of how the four major players in the market: Apple, Google, Nokia and BlackBerry (RIM) have deployed SECO approaches in the mobile application store market. The remaining sections of the paper are organised as follows: in Section 2 we present and overview of the SECOs under consideration and their business models. In Section 3 we conduct an analysis of the SECOs from both the external and internal perspectives. This section of the paper includes an assessment of the barriers to player participation and a general evaluation of the health of each SECO. In Section 4 we present a discussion of the business models and SECO deployment and finally in Section 5 we present the conclusions of this study and identify areas suitable for further study.

2   A Multi-case Study of Mobile OS-centric Software Ecosystems

In this study we have selected to examine the four leading mobile-OS centric SECOs. The Apple App Store, Google Android Market, Nokia Ovi Store and BlackBerry App World, are the largest and most dynamic examples of SECOs in the mobile os-centric market sector. Each SECO brings together large numbers of third party developers (players) who create applications for a specific set of devices. In this section for the paper we present an overview of each Application store and its associated business model. The general structure of the business process model of each case study revolves around, the registration process, development privileges, testing and technical support and distribution privileges. We compare the business process models of all the four cases in this study on those four factors. In order to better understand these four factors we define these factors as follows:

- *Registration process*: Anyone who is interested in developing an application under the platform of the SECO is required to register and obtains a particular ID and password. This registration may define user categories based on certain factors such as individual, company, or academia. The registration process may require some fees, which may vary for different type of roles.

- *Development process*: It elaborates and identifies the privileges/rights of different roles to have access and develop applications from the SECO platform. It also identifies any restrictions placed on the development process by the keystone.

- *Testing and technical support*: It defines the requirements of testing of the application developed under different roles. These testing requirements must be met before distribution of the application. Different roles may also have different level of technical support from the keystone company.

- *Distribution privileges*: It defines the procedure along with potential monetary and copyright privileges for the application to be distributed in the store.

These four factors have been selected as they are among the most central in establishing and ensuring the survival of an SECO [3]. The study examines how players are encouraged to join the SECO (registration); how they can interact with the SECO once established as a player (development); the level of support and requirements for testing of developed applications (testing and support) and finally the opportunities they have for distributing their applications (distribution). In selecting these four stages our intention is to establish how each of the SECOs have founded and continue to develop their ecosystem. Data was gathered from the individual portals of each SECO concerning these four main factors and a number of other actors of interest including the number of applications

Piers R.J. Campbell
Faheem Ahmed

available, payment methods and terms and the number of downloads from each SECO. The data was gathered in February 2010. A fundamental problem relating to data collection was that the individual keystones have differing attitudes to freedom of information and also at times present data using differing metrics.

Table 1: An overview of the 4 assessment elements for the Apple, Google, Nokia and Blackberry SECOs

	Registration	Development	Testing & Support	Distribution
Apple	Individual ($99/yr)	No Restrictions	Full Support & Apple Testing	Full
	Company ($99/yr)	No Restrictions	Full Support & Apple Testing	Full
	Enterprise ($299/yr)	In-house use only	Full Support & Self Testing	In-house Only
	University (Free)	Academic Use only	Limited Support & No Testing	Not Allowed
	Developer (Free)	Experience Use only	No Support & No Testing	Not Allowed
Google	Developer ($25 one off payment)	No Restrictions	Limited Support & No Testing	None
Nokia	Developer ($79 one off payment)	No Restrictions	Full Support & Nokia Testing*	Limited (20 Applications)
Blackberry	Developer ($299 per 10 applications)	No Restrictions	Full Support & Blackberry Testing	Limited (10 applications)

2.1 Case I: The Apple App Store

Apple has firmly established itself as a leader in the SECO field since the launch of its App Store in July 2008 (Site 1). The App store is a resource for software applications which can run on a variety of hardware devices created by Apple thanks to their shared platform. This shared platform grew from their adoption of the Software Product Line approach and has proven to be a highly beneficial development and economic decision. Since its launch in 2008 the offerings available via the App store has increased from 500 applications to over 185,000 in April 2010 [2]. This growth in availability of content has in turn generated increased downloading with over 4 billion downloads from the App store by April 2010, which has stimulated interest in developing applications and services, completing the cycle of development which is now prevalent in the SECO. In October 2009 Newsweek magazine reported that over 125,000 developers were involved in creating software for the App store [12], a figure which corresponded to 2 billion downloads and 85,000 available apps. As Apple continues to develop and release hardware devices capable of using the content available in their App store, such as the iPad it is clear that their App store will continue to grow in popularity, both for consumers and software developers [29]. What is also clear is that the actors in this SECO are both software organizations and individuals, and the design of the SCEO allows them to compete on an equal footing for customers.

2.1.1 The App Store Business Model

In designing access to the App Store, Apple has adopted a blended approach, encouraging software developers to become involved by offering significant access to their underlying platform through APIs whilst retaining effective control of their products. Indeed the latest release of the iPhone operating system (4.0) offers developer's access to 1500 new APIs, whilst Apple continues to garner criticism for having a closed operating system on its devices.

Joining the Apple SECO is a multi-staged process; developers must register with Apple as a Developer in one of four classes; Individual; Company; Enterprise; or University. Apple draws a distinction between Company, an entity that wishes to develop applications for general sale and Enterprise, an entity that wishes to develop applications for internal organisational use. It is also interesting to note that Apple imposes the same requirements on both Individual and Company classes of developer, both in terms of cost to join the SECO and division of sales revenue. Apple also opens its SECO actors who are not initially concerned with developing software or services for financial gain. Two reduced access classes of actor are available, University and Developer, which offer access to the APIs for iPhone, iPod and iPad but do not enable software creators to market their applications through the App store (these classes have additional feature reductions in terms of access to Apple Support). Joining the developer program (the Apple SECO) for these latter classes of membership is free of cost while the former classes of membership who which to develop applications for commercial purposes are required to pay membership fees which range from $99 to $299 per annum, as shown in Table 1.

Piers R.J. Campbell
Faheem Ahmed

Membership as a commercial developer of the Apple App Store brings access to Apples SDK, resources, forums, technical support (limited to two incidents per year) and test benches for Apple products (iPhone, iPad and iPod). Following developer testing using the available tools, applications are submitted for inclusion within the App Store, at which point they are tested and assessed by the application test team at Apple. The process is rigorous with many applications being rejected due to breach of conditions or lack of functionality. In such cases feedback is provided to the developers for improvement or modification of their application. Upon successful test completion the developers are enable to sell their applications to the public through the App store. Apple's business model splits the revenue from the sale of applications 70/30 (developer/Apple), with the developer responsible for setting the pricing structure for their creation. In addition Apple does not enforce any overhead charges with no hosting or marketing fees associated with the sale of application through the App store.

Apple's business model for the App store is both simple and complex as it carefully nurtures potential developers by allowing them free access to basic platform components allowing them to build their skill set. They also encourage the use of their core products in university courses by providing access to developer forums, SDKs and collaborative tools (Development team creation tool) thereby reaching a high number of future actors. However, the model also strictly controls deployment through rigorous testing of applications and places a number of barriers on entry including, comparatively high joining costs (an annual subscription), limited API access and tightly regulated and limited channel (App Store only) distribution.

2.2   Case II: Google Android Market

The central repository for downloadable software for devices that use the Android OS is the Android Market (Site 2). The Market was launched in October 2008 and currently has in excess of 50,000 applications available either free of charge or for purchase. Applications can be developed for any mobile device that runs the Android OS.

2.2.1   Google Android Market Business Model

The Google model treats all developers as a single class of actor (Table 1), making no distinction between individual developers and commercial entities. In order to register as a developer Google requires a single one off payment of $25 and agreement to their Market terms and conditions. The Android SDK provides developers with access to APIs and also development tools such as the emulator. The Android model allows developers to create applications which they can then distribute via the Android Market, directly via ftp or websites or alternatively via third parties. We will focus on the Android Market delivery channel in this paper. Following registration as an Android Developer, applications are developed and uploaded to the Market; Google enforces no testing beyond that of developer testing. Google will however investigate complaints from users regarding error prone applications or those applications that cause offence to users. When uploading applications to the market developers have the choice of making their applications freeware or paid and in the case of paid applications revenue is divided 70/30 between the developer and Google. Google imposes no charges on free applications that are uploaded to the Android Market. Furthermore no marketing, hosting or transaction fees are levied on any application submitted to the market (fees are included in the 30% split for paid applications).

The opportunity to engage with the Google Android Market is however restricted by geographical location (Site 3). In order to develop and sell (paid) applications developers must be resident in one of nine prescribed countries. Developers outside of these areas are currently unable to develop and sell applications via the Market. In addition to the geographical restrictions, Google also require that developers who wish to sell the applications must also navigate through the process of becoming registered Google Checkout Merchants. This requirement makes the process of selling applications more complex as individuals are required to register and ensure that they comply with the taxation requirement of their country of residence.

Free applications are less constrained both in terms of their development location geographically speaking and also in as much as they are free and do not require the complex Checkout Merchant account. The ability to develop and distribute free applications is limited to 147 countries. Confusingly developers in these countries may be able to develop and distribute free applications; however, they may not be able to download free applications from the Market in their own country. For example developers in Algeria can create, upload and publish freeapplications, but are not permitted to download applications from the very same Market under Google's current operating practices.
Despite being technology follower in terms of market entry Google's Android OS and its associated Market has demonstrated significant growth over the past year. Indeed most recent figures from comScore [9] show a 4% rise in market share over the 3 month period to January 2010, indicating significant growth in popularity for the Operating System Platform and its associated applications. This is doubtless due the open nature of Androids' OS that enables considerable engagement for developers. This is especially true when considering the delivery channels from Android Apps, which are not constrained to within the Android Market. Indeed it is possible for developers to download the SDK from Google without registering as a developer, create applications and offer them for sale (or freely) though their own web presence or a third party.

Piers R.J. Campbell
Faheem Ahmed

2.3   Nokia Ovi Store

Nokia of Finland is well known as the world's largest manufacturer of mobile phone devices. The Ovi store is Nokia's brand of Internet Services through which users have a choice of two delivery channels; the Ovi Store application which is loaded on devices or via the online line store (Site 4). The Ovi store was launched in 2007 and as of March 2010 was experiencing an average of 1.5 million downloads per day [24]. The main classes of applications supplied by the Ovi store includes; Games; Maps; Media; Messaging and Music. The Ovi store is the third party development portal for Nokia devices; the company retains its Embedded on Devices development channel for specific software applications.

2.3.1   Ovi Store Business Model

Nokia employ the same approach as Google by treating all third party actors as a single class (Table 1). All developers are required to register with the Ovi store and pay a one off registration fee of $79. Access to the SDK's is available without registration, however to deploy and sell applications developers must be officially registered. By registering with the Ovi Store developers have the ability to reach the estimated 50 million customers who own a Series 40 or S60 Nokia device. When registering, developers must choose between two types of publisher account. The first, Media Genre Account is designed for 1st party publishers who develop and own their content. Such accounts are also applicable for users who have exclusive right to distribute content on behalf of another party. This type of account allows users to upload and publish up to 20 applications, referred to as content items by Nokia, as they may include not only applications but themes and wallpapers which are not interactive in nature, at any given time. The second type of account is the Media Geo Account that is intended for 3rd party publishers who have the right to distribute content on a geographical basis. Such accounts many contain content which is not exclusive but which can be supplied to specific geographic locations. The availability of content from this class of account is limited by the Ovi Store management to "ensure content quality and discoverability is maintained" [23].

The Ovi store is somewhat unique in that it provides applications that run under a variety of operating systems rather than a single OS as is the case with Google and Apple. The supported technologies include Symbian, Java and Flash. As a result developers have a wide selection of development languages and tools. The Ovi Store also employs strict Quality Assurance standards on applications that are submitted for deployment. Indeed in the case of Symbian and Java based applications Nokia requires that applications satisfy the testing requirements equal to either Symbian Signed or Java Verified status. Indeed until recently Nokia required that all applications running on either of these platforms should have been approved by the relevant body, Symbian or Java (Site 5). This requirement proved unpopular as the cost associated with these accreditation procedures (over $200 in the case of Symbian) was deterring individual developers from creating applications. As a result the Ovi Store no longer requires official Singed or Verified status, however, applications should still be tested to this level and all applications submitted to the Ovi Store undergo testing before being offered for sale. In addition developers are required to sign their content using either Versign or Thawte. Following this process, applications are tested by the test team within the Ovi Store prior to their acceptance for distribution.

Once an application has been accepted to the Ovi Store the sales model follows that described for Apple and Google, in that the developer is not charged for hosting or marketing costs and revenues are divided on a 70/30 basis with the Ovi Store. One important difference with the Ovi model however, is the opportunity for users to download applications via their service provider rather than directly from the Ovi Store. In such cases the user is billed by their provider for the application. Under such circumstances the service provider typically receives 40-50% of the revenue from the sale of the application and the remaining percentage is split between the developer and Ovi Store according to the above revenue split structure. Developers can select whether they wish the application to be offered via both of these channels (Ovi Store, with Credit Card purchase or Ovi Store and Operator billing). Pricing in the Ovi Store is less flexible than other approaches in that developers are constrained to pre-defined pricing points that range from Free to 100 Euros per application. Therefore developers are unable to set their own price and must select from the pre-defined pricing points.

2.4   BlackBerry App World

The BlackBerry from Research in Motion (RIM) is the second largest selling smartphone OS in the world with approximately 20% of market share, placing second to Nokia's Symbian OS. The BlackBerry is however the leading choice for business phones use. RIM offers applications for download through its BlackBerry Application World service, which launched in April 2009 (Site 6). Initially launched as a web-based portal accessible via portal devices, App World is now accessible via desktop computers and mobile devices.

2.4.1   The App World Business Model

The App World business model outlined in Table 1 is somewhat more complex than the offerings from Apple and Google in terms of developer involvement. In addition the paid applications (free apps are also available) offered also tend to be more expensive than other providers, with applications ranging in price from $2.99 to $999.99. The App World also charges higher registration charges ($200) to become registered as an application developer in the

Developer Zone. BlackBerry is selective in terms of accepting developers to their program and only developers who create *quality* applications are admitted. Those developers who fail to achieve the required level of quality are refunded their application fee of $200.

Multiple development environments are available to developers, although the common underlying technology is Java for the majority of BlackBerry applications. Developers can choose to make use of four main development environments:

- BlackBerry JDE

- BlackBerry JDE plugin for Eclipse

- BlackBerry Theme Studio

- BlackBerry Widget SDK

Following the development of an application using one of the environments identified above developers must submit their application to BlackBerry for review and testing. Initially BlackBerry offered very favourable terms to developers whose applications were accepted into the App World, with BlackBerry taking only 20% of the revenue from application sales [11]. This business decision may have been taken in light of the higher app costs that resulted in the 20% share being significantly higher than the 30% charged by other online stores. However, as BlackBerry has recently discussed amending the revenue split to 70%/30% (in line with Apple, Google and Nokia) the decision may have been aimed at attracting developers to produce content for BlackBerry rather than other OS's, given BlackBerry's belated entry into the market.

A further drawback of the App World is its geographical limitations. Indeed to date there are only thirteen countries in which it is possible for developers to sell their applications. However, free apps are available in another 42 countries, including Australia, China, India, South Africa and Poland, perhaps indicating that BlackBerry's main focus is on the sale of paid apps in their main markets, rather than the development of new or existing minority markets. This approach also highlights that BlackBerry is focusing primarily on the business users rather than domestic customers.

Perhaps the combination of geographical restrictions, high entry requirements (to the App World for developers) and a limited selection of Apps has driven the 3rd party App scene which has grown around Blackberry devices. Alternative vendors such as CrackBerry allow developers to submit their applications, fee free, receive a review within two days and sell their Apps (if accepted) receiving 80% of the net revenue. Indeed the volume of apps available from 3rd party portals and stores would appear to significantly out number those available through the App World.

3   Assessment of the Ecosystems

Assessing SECOs requires consideration of internal and external elements referred to in literature as their external views and internal characteristics. This assessment includes an evaluation of the current *health* of the SECOs in addition to the barriers which prevent potential players from becoming engaged with the ecosystem and the orchestration techniques used by the organisations to encourage the engagement of such potential players.

3.1   External Views of the SECOs

We have presented an overview of the business processes of four leading companies currently involved in the mobile computing market. For each we can clearly see that a Software Ecosystem (SECO) has grown around the organization and its technology. As the SECO has grown around the technology offered by each of these organizations they can be seen as central to the SECO and are effectively leading the collaboration within their SECO. BaIalyer and Lee [3] and Iansiti and Levien [17] describe these organizations as Keystones, as they provide the fundamental building blocks around which the SECO can grow. Furthermore a keystone should also provide focus, identify opportunities, provide leverage, define standards and practices, foster specialization and increase in value with the number of participants in the SECO, according to Hagel, Bown and Davison [16].

When defining an SECO Jansen, Brinkkemper and Finkelstein [18] present restriction boundaries, which can be used to generally, classify the type of ecosystem. The four classifications, which they present, are:

- *Market* - A SECO centred around one specific market, such as the Computer Aided Design (CAD) market, the portable music player market, Participants in these market-oriented ecosystems function as a unit (at the least) in that they supply customers with similar products and the loosest relationships amongst them are competitive.

Piers R.J. Campbell
Faheem Ahmed

- *Technology* - A SECO can be based on a specific technology, such as a programming language, or the Internet Protocol Version 6 (IPv6). Participants in these ecosystems typically are of any kind, although the owner of the technology's intellectual property is generally found to be a keystone player in the SECO.

- *Platform* - SECOs can be focused around one specific platform or product, such as the Eclipse platform, the Microsoft CRM platform, and the Ruby on Rails framework. Platforms are characterized by the fact that their functionality can be extended by the addition of components (generally in a native format) or the presence of an Application Programming Interface (API). Platform SECOs are generally easily identified and enable commoditization of functionality packaged in components and frequently sold in specific component marketplaces (such as the iPhone's AppStore or the Android Market). By definition the platform supplier is a keystone firm.

- *Firm* - SECOs can also be defined around one firm, such as the Microsoft SECO, the Google SECO, or the SAP SECO. The firm plays the role of keystone supplier in several platform ecosystems. An interesting property of firm SECOs is that dependent on the strategy of the firm there exists strong or weak cohesion between the different participants.

If we apply these classes to the SECOs examined in this study it is clear that each falls within the boundaries of the Platform type, but also in their current guise, within the boundaries defined for Firm SECOs. It is obvious that in three of the SECOs examined Apple, Nokia and BlackBerry there is a patent development around the organizations SECO. However the classification of Google is less straightforward. Certainly the SECO is tied to the platform used by the keystone (Android OS), however this platform is Open Source and as such the SECO can and does involve other actors who could themselves be classified as keystones. HTC in particular has been a clear adopter of the platform for their mobile devices.

Bosch's Software Ecosystem Taxonomy [5] further defines the relationship between the elements as being an operating system-centric ecosystem in which the ecosystems are domain independent and 3rd party developers provide applications, which give added value to customers. Clearly in such an OS-centric environment the growth and development of the SECO is inextricably linked to the success or failure of the underlying OS and in the case of mobile devices the interaction between the OS and the hardware device. This is clearly the case with Apple's iPhone, which, despite having a reduced feature OS (at the time of launch) when compared to other mobile device operating systems, was highly popular due to its hardware design and user interface in particular. Indeed the iPhone example further supports Bosch's premise that in order to remain popular and commercially viable the underlying OS must evolve as the SECO evolves. The subsequent updates to the iPhone OS have included features requested by end users and SECO participants alike, including cut and paste and multi-tasking. Such incremental updates have been met with much applause and excitement, despite the same functionality having been available an alternative devices and operating systems for some time.

When describing the participants (non-keystones) in the SECOs a variety of terms have been applied including: actors, niche players, participants and followers, as used by Jansen et al, Hagel, Brown and Davison, Iyer and Iansiti and Levien respectively [3], [16]-[18]. What is clear is that in each of the SECOs examined there is the participation of a single keystone and a number of 3rd party developers. These 3rd parties consist of business entities, individuals and groups of individuals who are employed in the development of applications for one or more of the ecosystems examined. This involvement of 3rd parties is an essential element of software ecosystems and is discussed further in the following section of this paper in which we present an assessment of the health of each of the four SECOs.

3.2   A Health Check of the Ecosystems

Iansiti and Levien propose that the health of an SECO can be assessed by examining the prevalence of three features within that ecosystem, Robustness, productivity and niche creation [17]. Robustness is a measure of how well an SECO can recover from major issues such as a keystone leaving the ecosystem, desertion of a significant number of niche players, or from competition from new technology, which competes directly with the existing SECO. Productivity deals with the activity within the SECO and examines factors such as growth of business and increases in actor (player) involvement in the SECO. The final feature for assessing the health of an SECO is niche creation and this feature examines the SECOs ability to create new opportunities for new players to join the ecosystem and for existing players to move into new areas. A summary of the available information for each SECO is presented in Table 2 below. While there are a number of other measures which can be applied to assess the health of a business venture, revenue, profit, number of customers and customer churn, to name but a few it is difficult to access data for many of these measures. For example there are no statistics readily available concerning how many players (developers) for each SECO are *active* i.e. producing new application content on a regular basis. Also in the case of Google it is not clear how many end users download application content from 3rd party channels rather than through the official channel, the Android Marketplace. As a result this study adopts the methodology proposed by Iansiti and Levien and employed by Jansen et al [18] as the most robust approach to assessing the health of software ecosystems.

Piers R.J. Campbell
Faheem Ahmed

The Apple App Store SECO can be seen as healthy based on these assessment factors. The ecosystem is certainly productive, with the largest App set of the four (185,000) and the most significant increase in new offerings from December 2009 to January 2010 (13,865 new applications). Based on these figures the App store is also positive in terms of niche creation, indeed many players have developed App's solely for the iPhone OS platform, choosing to ignore Android, BlackBerry and Nokia, at least in the short term. When assessed from the perspective of Robustness the health of the SECO is less clear. Certainly Apple currently offer three devices upon which their current platform operates (iPhone, iPad, iPod Touch), however should Apple choose to exit from this SECO there would be no further device or platform enhancements and its likely that the SECO would degrade over time.

The same is also true of the BlackBerry SECO, which is tethered to the BlackBerry platform and would be unable to survive the keystone's withdrawal from the SECO. BlackBerry has also struggled in terms of productivity and niche creation. The SECO has been negatively affected by interest in the iPhone ecosystem and has struggled to attract new players into its SECO. This can be observed by the limited, by comparison to both Android and iPhone, application availability (less the 6,000) and in particular the number of new applications (501 during the period Dec 09 – Jan 10) being created within the ecosystem.

By comparison to Blackberry the Google Android and Nokia Ovi SECOs are more robust. Both offer their platform (Android OS and Symbian OS) as open source, and in the case of Android, actively support the use of the platform on multi-vendor devices. The Android SECO is however significantly ahead of its Nokia rival in terms of productivity and niche creation, with considerably more available and new applications; however Nokia did enter the market later than Google and current application download figures suggest that their ecosystem is continuing to build momentum. Overall the four SECOs examined appear to be in good health, however the keystone of each ecosystem has clearly taken on the role of dominator as identified by Paine [25]. Commenting on the presence of a dominator, Jansen et al point out that in a number of examples, the dominators ultimately either destroyed the SECO or had to be regulated by external factors in order to enable the SECO to survive. It is too early to predict how each of the SECOs examined here will develop overtime, but it remains likely that some regulation will be needed in the future [30].

3.3   Internal Characteristics

In the previous section we examined the health of the SECOs using indicators developed by Iansiti and Levien. Whilst this is a useful exercise to assess the current status of an SECO it presents only a snapshot of the SECO at a moment in time. In order to fully assess SECOs it is therefore necessary to examine the factors which have contributed to its current health state. One such set of factors are the internal characteristics of the SECO. Exploring the internal characteristics of an SECO requires the examination of the interaction between the players (and potential players) and the ecosystem. The central aspects of concern when examining the interactions of the four ecosystems are firstly, the barriers to entry for potential players and secondly, the internal stability of the SECO.

3.3.1   Registration Process

The potential barriers to entry for any SECO include the availability of development tools, access to the platform and ultimately accessibility to the market through which applications can be sold. In all of the SECOs examined the initial barrier to entry for potential players is the requirement to register as a developer with the keystone of the SECO. Each keystone has defined its requirement to registration differently with all requiring some level of financial contribution. Apple imposes a $99 fee (based on the developer class of membership), which must be paid annually to continue engagement with the SECO. Google and Nokia also impose a registration fee ($25 and $79 respectively); however this is a one-time payment and currently gives permanent access to the SECO. BlackBerry charge the highest registration fee, $200, and impose the additional restriction of limiting application submissions to ten based on this fee. Submission of more than ten applications (which also include revisions of existing applications) requires an additional payment of $200, which entitles the developer to submit an additional ten applications.

3.3.2   Application Testing

Once a developer has successfully registered, as part of the SECO the next barrier to entry is the testing of any application that is submitted to the SECO. The Apple, Nokia and BlackBerry SECOs require that applications submitted for use in the SECO undergo testing by the keystone entity. This process is intended to ensure the quality of applications in the SECO and to protect the end user base, which is currently tied to the SECO through the keystone and its reputation. The process is rigorous and Apple in particular, perhaps due to the sheer volume of players and apps, is renowned for being particularly demanding during the testing phase. Google's SECO represents a significant departure from this approach. Players are able to submit applications to the SECO (Android Market) with the burden of testing being placed firmly on the developer. Google examines and tests applications only following complaints from customers. This departure in testing practices by Google represents a significant reduction in the barriers to access and is perhaps why the Google SECO is growing rapidly when compared to more mature ecosystems such as Apple's. Indeed testing is such a serious barrier to player participation that Nokia removed the requirement for applications to be certified (Symbian Signed or Java Verified), a process which added expense for developers, and Nokia now requires that applications should be of a standard equal to that for certification.

Piers R.J. Campbell
Faheem Ahmed

Table 2: Comparison of performance statistics in the Apple, Google, Nokia and Blackberry SECOs

	Apple	**Google**	**Nokia**	**BlackBerry**
Free Apps	Yes	Yes	Yes	Yes
Paid Apps	Yes	Yes	Yes	Yes
No. Apps Available	185,000	38,000	6,843	5,392
No. Downloads	4,000,000,000 (Total to date)	400,000,000 (Total To Date)	5,000,000 (per day)	100,000,000 (Total To Date)
Registration Fee	Yes ($99 - $299/annum)	Yes ($25 – one time fee)	Yes ($79 or €60 – one time fee	Yes ($200 – 10 apps)
Developer Revenue Share	70%	70%	70%	80%
Potential Customer Base	85,000,000	Not Available	50,000,000	41,000,000
No. New Apps (Dec. 09 – Jan 10)	13,865	3,005	734	501
Apps Available outside Store	Limited	Yes	Limited	Limited
Payment Methods	iTunes	Paypal	Credit Card Operator Billing	Google Checkout Operator Billing
Launch Date	July 2008	October 2008	May 2009	April 2009
Subscription Billing Allowed	Yes	No	No	No
Minimum App Cost (Ex. Free)	$0.99	$0.99	$1.31 (€0.99)	$2.99
Maximum App Cost	$50	$200	$131.29 (€100)	$999.99
Certification Requirement	Developer Cert. Distribution Cert.	Developer	Developer	Developer
Submissions Reviewed & Tested	Yes	No	Yes	Yes
Software Platform	iPhone OS	Android OS	Symbian OS	BlackBerry OS

3.3.3   Internal Stability & Rewards for Engagement

Jansen et al [18] define stability as a determining internal characteristic of software ecosystems. In particular the faithfulness of players who become part of the SECO. In other words, do players enter and leave the SECO frequently or do they remain a committed element of the ecosystem for a significant period of time. As each of the SECOs examined are still immature, it is perhaps too early to draw any concrete conclusions concerning their stability and the faithfulness of their associated players. However, Jansen et al also point out that techniques can be applied to improve the stability of an SECO, a process he refers to as Orchestration. One such orchestration technique is tenancy, which concerns the price of participation. We have already explored some elements related to tenancy when examining the costs of registration (section 3.3.1). This concept may also be observed within the Nokia SECO, which initially required developers to certify their applications (see section 3.3.2). These additional costs (approximately $200 per application) may have contributed to instability within the SECO, with players choosing to operate with alternative ecosystems in which the cost of participation was lower.

A further example of tenancy as mentioned by Jansen et al is the revenue that is retained by the keystones in each of the SECOs. When selling an application in any of the application stores there is a division of revenue between the keystone and the player. In order to remain competitive each of the keystones (with the exception of BlackBerry) has set this split at the level of 70/30 (player/keystone). Meanwhile BlackBerry has opted to offer players more favourable terms in respect to revenue share (80%/20%) as a clear incentive for players to join their SECO rather than, or in addition to those of their competitors. This decision was most likely taken due to BlackBerry's late entry into the application store market, and may change as their SECO matures. Regardless, it is important to note that all SECOs

Piers R.J. Campbell
Faheem Ahmed

have attempted to protect their ecosystems by placing some barriers on accessibility. However, they have also need to encourage engagement with the ecosystem in order to ensure its survival and growth.

4   Discussion

The popularity of SECOs is increasing because they provide a novel way of developing business and integrating software development activities. From an open source software development viewpoint, individuals are contributing because of their technical interests and other non-economic factors, but interaction with a SECO also provides opportunities for developers to earn money and satisfy their thirst for creativity [21], [28]. From an organizational viewpoint Keystones must embrace the SECO concept in order to deliver the range of functionality demanded by users and ensure that they remain competitive within their market segment. The mobile operating system market is certainly one of the most competitive technology domains, currently however Apple has also announced its intention to widen their involvement with ecosystems to include an App Store for non-mobile devices that run their larger Mac OS X operating system. In this paper we presented an examination and assessment of the four leading Software Ecosystems in the Mobile Operating System domain from the perspective of their business processes and in particular their current health and potential for continued viability.

The SECOs are anchored by keystone entities from Apple, Google, Nokia and RIM (BlackBerry) and exist in their individual ecosystem with a myriad of players, both individual developers and commercial entities who provide end user applications. We identified that all fall within the classification of Operating System-centric platform based software ecosystems. An analysis of the health of each SECO identified that in general terms each of the four SECOs are healthy; however, a fundamental threat remains to their longevity due to the potential for domination by keystones. This is clearly a significant threat in the Apple SECO, which applies rigorous assessment of applications before access is granted to the SECO. It is also a potential threat for the Nokia SECO, however various alternatives to the Nokia App Store and Google Marketplace indicate that this issue is less of a concern to these organizations. Robustness also remains a concern for SECOs such as Apple and BlackBerry that are tied to the keystones closed Operating System and limited mobile device range. We further examined the internal characteristics of each and identify the barriers in place that prevent players from engaging with the SECO. Our analysis also identifiesthat the orchestration techniques are in place to encourage player participation. However, the majority of the keystones currently employ similar techniques with only Google's completely open accessibility being a significant differentiating factor. We further conclude that SECOs are currently too immature to enable a performance and evolution analysis to be conducted.

We observed that all four SECOs employ a similar business model that encourages participation of players in the development of end user applications, but which also attempts to retain control of their market space, and in addition attempts to dominate the mobile device market at the expense of the other SECOs. A key concern for each organization is introducing the flexibility to encourage potential players to interact with their SECO and develop applications, whilst retaining control and guaranteeing the quality of the applications and the end user experience. This is a key concern as the market is still relatively immature and end users dissatisfaction with applications may also affect their views of the mobile device and/or platform, both of which are products from the SECOs keystone entity.

It is impossible to predict the future development of this market space as the organizations and SECOs are still too novel to fully assess their ultimate potential. Certainly Apple has a significant advantage over the competitors in terms of the sheer numbers of available applications (185,000) and also mobile device types (iPhone, iPad and iPod Touch). However, Google is making significant progression due to its open source OS (also a feature of Nokia) and the decision to partner with multiple device manufacturers in order to increase options for consumers. Nokia has a huge potential customer base (50 Million device users) and are disadvantaged due to late entry into the market, as too is BlackBerry.

We note that the methods of orchestrating players are consistent as each keystone attempts to attract and retain the players with its SECO. All offer very favorable terms to players, the general trend being a 70% 30% split of net revenues from sales (Apple, Google and Nokia). However there are some important deviations from this approach. In the case of BlackBerry a larger split is offered to the players in order to attract new talent to the pool of developers, which is currently limited by comparison to Apple and Google (BlackBerry offers only 3% of the applications available through Apple). BlackBerry also enforce the most stringent barriers on players joining the SECO, perhaps to ensure quality of applications as BlackBerry's main customer base are business users who would be less willing to accept poor quality application experiences and who are likely less interested in Entertainment or Leisure based applications.

Google has diverged significantly from the other SECOs by making their SECO the most assessable of the four through a variety of novel measures. The registration fee is significantly lower than their competitors ($25), there are no testing procedures for submitted applications (other than developer testing), the OS platform is Open Source (Nokia's Symbian OS is also Open Source), there are a variety of mobile devices, from multiple vendors actively employing their OS and developers are free to offer applications through delivery channels other than the Android

Piers R.J. Campbell
Faheem Ahmed

Market. These features are the elements that are driving the significant increase (3000 new applications between Dec. 09 and Jan 10) in Google Android adoption and application development.

The possibility of Software Ecosystems on a large scale has been proven by the approaches of these four leaders; indeed software organizations in other market spaces are now examining how collaboration and engagement can be implemented in their own areas. However the fundamental question regarding the future of mobile application stores and their associated ecosystems is an issue that is currently affecting every aspect of the software industry, is the future open source or proprietary software? It will only become clear overtime and with careful future studies as to which business model approach is most suited to this emerging market, however, in the current situation it appears that pioneers in the field with carefully aligned platform and device packages are outperforming those who have adopted an open approach. This may change as Google could consider offering a similar Application Store Environment as part of its Cloud computing development, which would enable the full connectivity of mobile, desktop and web based computing.

5   Conclusions & Further Work

Software Ecosystem's are a departure from the traditional approach to software design and construction. The same is true of Application Stores, which allow customers to access applications and services in new and exciting ways. The demand for increased variety of applications has lead mobile software industry leaders to examine news channels for supplying customers and new approaches to designing applications based on their core products. This paper provides an investigation to the operation of four leading Applications stores, which serve as delivery channels for mobile-OS centric software ecosystems. A comprehensive examination of the SECOs architectures is presented in terms of their internal and external characteristics, in addition to an elementary assessment of their health. The material presented serves as a useful resource for interested parties in the mobile software design field and also for those active in the Software Ecosystem domain. The results of the study show that the mobile-OS centric SECO sector is growing rapidly. The serge in this market is primarily due to Apple 's early adoption of the SECO concepts and the then rapid response of the other major keystone entities. As a result, Apple has built a robust SECO with high numbers of players, clearly exploiting the first-mover advantage as identified by Grant [14]. However, Google shows clear signs of growth and their differing approach, in terms of encouraging players to join and enabling a higher level of openness (when compared to the others), shows that they have perhaps learned valuable lessons from Apples' early entry into the sector and are exploiting the second-mover advantage [26]. The study also clearly highlights the interest in this type of SECO and that consumers and developers are excited by the opportunities offered by these developments.

The paper serves as a concrete application of the theory developed recently regarding the creation of ecosystems in the software domain. Furthermore we identify the fundamental differences between implementations and hypothesize regarding the motivating factors for these differences in business models. To that end this paper serves as suitable resource for driving forward research in the field of Software Ecosystems, in particular the questions raised with regards to proprietary and open source operating system platforms in the mobile sector. As the performance of the Google SECO has shown there is a high demand for more openness from consumers and developers alike and in a marketplace were the rewards for entry in to a given SECO do not vary greatly, players will be attracted by different recompense, it is therefore essential that in order to ensure the longevity of an SECO keystones are aware of the barriers or perceived barriers (i.e. lack of openness) which might ultimately deter players from joining the SECO. The study ultimately shows that there is currently no clear winner in terms of orchestration approach, which is likely due to the immaturity of the business sector. Therefore this study is intended as a measuring tool to enable the future development of SECOs in the mobile-OS centric sector.

Websites List

Site 1: Apple iPhone Application Store
http://www.apple.com/iphone/apps-for-iphone

Site 2: Google Android Marketplace
http://www.android.com/market

Site 3: Google Android Developer
http://developer.android.com/

Site 4: Nokia Ovi Store
https://store.ovi.com/

Site 5: Symbian
https://www.symbiansigned.com/app/page

Piers R.J. Campbell
Faheem Ahmed

Site 6: BlackBerry App World
http://na.blackberry.com/eng/services/appworld/

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Piers R.J. Campbell
Faheem Ahmed