Smart Transitions

The Technology Transition in the Smartphone Industry Since 2007

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Introduction

The gap between desktop computers and mobile devices has diminished since the word “smartphone” entered into the public consciousness. In 2010, smartphone manufacturers began to ship over 100 million devices per quarter, surpassing personal computer shipments for the first time.¹ Smartphones are experiencing accelerating rates of adoption—one-third of mobile consumers in the United States own a smartphone.² Nielsen predicts that by the end of 2011 U.S. consumers will own more smartphones than regular phones. This technology disruption has created a lucrative battle for market and profit share amongst both incumbents and new entrants in this fast-paced industry.

Smartphones have triggered a transition that will affect all of the participants in the cell phone industry. Handset manufacturers are now in a race to pack additional features into these devices, software developers are constantly adding new applications to meet the needs and entertainment of consumers, and network operators are installing more infrastructure to meet the growing consumer demand for data speed and ubiquitous connectivity.

To understand the smartphone transition in terms of its impact on the smartphone industry and its market, this report introduces theories on the mechanics of technology transitions and explains, to the extent possible, how these theories are useful for analyzing the dynamic changes in the mobile industry. A number of key elements, including changes in hardware development, software choices, and business strategies of the relevant firms, will be critical for smartphones to continue expanding. Finally, this report will examine how this transition is having both positive and negative impacts on peripheral industries.

The Smartphone Market Today

The rapidly evolving and expanding smartphone marketplace is a highly competitive and challenging space for both incumbents and new entrants. It is characterized by strong rivalries, rapidly evolving technology, short product life cycles, aggressive pricing, and rapid imitation. The key players are in a race to drive smartphone sales and gain market share. The major device manufacturers in the global smartphone market include Nokia Corporation (Finnish), Samsung Electronics (subsidiary of the Korean Samsung Group), LG Corp (Korean), Apple (U.S.). The software producers in this industry are Apple (U.S.), Google (U.S.) and Microsoft (U.S.). Smaller participants include Motorola (U.S), Sony Ericsson (a joint venture between Japanese Sony Corp and Swedish Ericsson), HTC (Taiwanese), ZTE (Chinese), and Huawei (Chinese). The positions of these key players are constantly changing as device trends and popularity are changing on a daily basis.

![Figure 1: Worldwide Cell Phone Market by Device Manufacturer in 2009 and 2010.](http://www.gartner.com/ids/page.jsp?id=1543014) Percentages sourced from Gartner 2011

While Gartner reports that Nokia, Samsung, and LG are the top manufacturers of mobile devices, in the United States, Nokia and LG hardly have a presence in the smartphone market. Worldwide, all three companies are losing market share to Apple’s iPhone. The “other” category of device manufacturers (see Figure 1) grew from 20 percent to 35 percent from 2009 to 2010. These “other” manufacturers include Japanese companies such as Sanyo, Panasonic, and Toshiba and Chinese and Taiwanese brands such as ZTE, HTC, Huawei, and Lenovo (all of which have grown in large part because of Google’s Android).
In Figure 2, the assessment of global consumer market share by operating system (OS) illustrates that Google’s Android (Google, 23 percent) has increased its stake by well over 800 percent in one year, surpassing both Research In Motion’s Blackberry OS (16 percent) and Apple’s iOS (16 percent). Overall, Nokia’s Symbian OS still commands the largest percentage, but that lead is rapidly decreasing due to strong gains from Android and Apple. Symbian’s decline can be attributed to the software stagnation of Nokia’s phones, the company’s lack of offerings for the U.S. market, and global component shortages. Google has taken the lead in the mobile OS space by distributing Android as a free product, for use by any device manufacturer. Nokia was initially pursuing the same path with the development of the “MeeGo” operating system, but that project was replaced by a strategic software licensing partnership between Nokia and Microsoft in early 2011.

Figure 3: U.S Market Share by Smartphone Operating System, January 2010-January 2011. Source: ComScore

Figure 3 shows that Android commands 33 percent of the U.S. market, Apple has
retained 25 percent, while RIM has declined over the past year to 29 percent.\footnote{Henry Blodget, "Android is Destroying Everyone, Especially RIM- iPhone Dead in Water," Business Insider, April 2, 2011.}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure4.png}
\caption{Market Share vs. Profit Share for Device Manufacturers, 2010. Size of bubble indicates profit. (percentages sourced from Gartner and asymco)}
\end{figure}

It is also critical to note that while market share is representative of the sales successes
of respective firms, it does not necessarily correlate to the profitability of the companies.

Apple’s earnings total more than the world’s three largest handset makers combined (Nokia,
Samsung, and LG), yet its phones dominate only three percent of the market (Figure 4).

Apple and Google are the clear market leaders overall, while Nokia is rapidly losing
market share. Other contenders include HTC, Motorola, Samsung, and LG, all of which are
making use of the Android OS. However, the cellular market is unpredictable and there are no
valid projections for long-term winners and losers. The smartphone market is likely to look
significantly different over the next few years.

II. Analysis of Technology Transitions

There currently is no reliable theory or method that exists which can accurately predict
the future of a market with any measurable accuracy. Analysts have examined case studies of
previous technology transitions in an effort to determine an accurate methodology for predicting
future transitions; however, the applicability of the existing techniques in published works proves
less than helpful in this respect. The theory exploration in this analysis examines two prevalent and relevant approaches to the smartphone transition. One of these methods examines a transition by studying the stages of the technology's life cycle—invention, adoption, and its eventual replacement—an approach that uses a characteristic s-curve to represent each transition.

The diffusion theory, which examines the s-curve of a technology transition, illustrates that the diffusion and performance of a technology is slow in its beginning stages, but increases in relevance and capability over time, and eventually flattens out as it is supplanted by a new technology with its own s-curve. While diffusion theory is useful in examining previous technology transitions, such as the diffusion of the automobile into society, its application becomes problematic when older, existing technologies are not completely supplanted by a new technology in transition. Ansari and Garud argue that in some cases a technology is not always completely replaced by a new technology. For example, during the switch from second generation (2G) to third generation (3G) cellular networks, a new improved 2G network was developed as a stepping stone between 2G and 3G, called 2.5G, which kept 3G from completely eclipsing the existing 2G technology.

A more effective approach than diffusion analysis for examining a technology during a transition is one that includes an examination of the social factors that influence technology transitions, using a research method called the multi-level perspective (MLP). This tool allows an analyst to discover links that are not considered in the traditional s-curve analysis; the sociology of technology. While no approach is perfect, it is critical to take into account all of the

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interpersonal factors that drive technology disruptions, as individual technologies do not cause transitions on their own. Geels argues that, "only in association with human agency, social structures, and organizations does technology fulfill functions." These sociotechnological changes involve not only a change in technology but also shifts in user practices, product regulation, provider infrastructure, and the cultural significance of a given technology. This approach, however, cannot predict a which technology will be successful during a transition, since such tools do not yet exist.

Analysis of the Technical Transition in Mobile Telephony

The smartphone technology transition is best analyzed in its current state by building a sociotechnical configuration with nodes representing each of its primary characteristics (Figure 5).

![Figure 5: Sociotechnical Configuration in Mobile Telephony](image)

All of these elements are interlinked by varying degrees, which are based on the levels of communication between interested parties. For instance, service providers, communication
networks, sectoral regulations, markets and the phone are closely linked, while the users are less related to the sectoral and political regulations affecting the transition. The sociotechnical configuration as it exists in Figure 5 did not exist for previous generations of cellular technologies. In fact, nearly all of the nodes changed during the transition to smart communications.

Since 2007 the mobile telecommunications industry has been in a state of flux, due to the introduction, rapid adoption, and evolution of the smartphone. While smartphone penetration in the United States as of late last year was only 28 percent, this product segment is projected to accelerate in growth. Several incumbent companies are having trouble adapting to this rapidly changing market. The smartphone's popularity, coupled with the rise of related mobile e-commerce application channels, have unexpectedly disrupted the market valuation and share of many of the telecom sector’s largest companies.

The MLP is useful to illustrate how change occurs in this technology regime. Three levels compose the multi-level perspective: the niche level, the regime level, and the landscape level. It is proposed by those utilizing the MLP that technology change during a transition is initiated at the niche level, which is shaped by the existing regime of that technology. An example of a niche level technology change might be the incorporation of an MP3 player into the first iPhone. These niche level technologies evolve, and if they are successfully adopted by the regime, a modification of the regime can occur. As the regime layer is modified, the landscape, which looks at the collective elements of the regime level, is transformed. Landscape level change indicates a significant shift of a technology occurring on a macro level, like a significant cultural change involving how the user experiences the technology.

Geels suggests that the movement of a technology from the niche to the regime level is a result of a process called “niche-cumulation,” in which the technology gradually continues to expand in use among many different niches. As the niche-cumulation expands, the technology improves and starts to affect more sociotechnical elements of the technology network. An
example of this is the increase in use of location-based services on smartphones. Originally GPS was included in phones as a way to assist users with directions, with a software like Google Maps, to a specific location. However, as applications began incorporating more location-based services, GPS became a mandatory feature of smartphones. Even so, GPS is not always desired by consumers due to privacy concerns. Yet this example illustrates how the niche consumer technology of GPS—originally only on iPhones—gradually became a mandatory smartphone component, through regime to landscape-level change.

Why do Good Incumbents Make Bad Decisions During Transitions?

The MLP sheds light on the factors that affect technology transitions, but it does little to identify why some large, seemingly successful and functional companies fail to take advantage of a new, disruptive technology and its resulting transition.

Christensen defines a technology as disruptive when it targets “non-consumers,” meaning that the new technology builds the size of the market by attracting new consumers that were not otherwise adopting the technology\(^9\). This disruption changes the market by augmenting the consumer base. The incumbents in a technology market typically have a defined customer base that uses existing technology and infrastructure. When a shift in consumers occurs, incumbents are often reluctant to modify their existing products, out of the fear that they will lose their most profitable assets and their shareholder’s confidence. As a result of this risk-averse behavior, incumbents typically choose profitability over innovation by developing existing products rather than researching new and untested ideas for an emerging consumer segment.

Large corporations are also primarily focused on large structural and financial growth, which is also the main driver of their shareholders. Disruptive innovations may not produce the

immediate revenue growth that large companies require, as new ideas often require years of labor and large investments.

One technology transition that is particularly applicable to this smartphone analysis is the shift of computers from the office to the home. In 1984, Apple introduced the first mainstream desktop computer, the Macintosh, and marketed it as an entertainment device for everyday people. That segment of the population had never been targeted by incumbent companies like IBM and Compaq, which were more focused on creating enterprise-scale computers for productivity purposes. Apple succeeded in creating a niche market that succeeded in gaining the attention of everyday people, leading to continued growth and profitability of the company. One of the reasons why these computers succeeded, is because Apple had no previous business strategy or products to maintain, allowing it to be more flexible and innovative than its peers. Some companies, however, wait to adopt a disruptive technology when the market for it becomes more mature. Ultimately, IBM entered the consumer computing space in the late 1980’s, which only added to its profits from enterprise servers and services, as Microsoft’s Windows was propelling the rapid growth of the market.

In the mobile communications realm, the introduction of Apple’s iPhone created a market for smartphones that did not previously exist by targeting the non-consumer. Apple had no previous experience with producing or selling mobile phones, but it managed to initiate the smartphone transition currently in progress. Another relatively early entrant to the smartphone was also a non-incumbent; Google began competing for market share with Apple in 2008, a year after the iPhone was released.

Both Apple examples demonstrate that companies can enter new markets and succeed against the predominant companies if they target an untapped segment of customers. Incumbents in the telecommunications sector are now having difficulties making their hardware and software offerings profitable in the face of their newer and more agile competitors. The
overall market for the smartphone is still in a nascent stage, so the decisions that all of these companies make in the coming years will alter the field significantly.

III. The Hardware Transition

Cellular device manufacturers and infrastructure developers have felt significant pressures of this industry disruption. The markets in which they ship and certify products has scaled from regional to global and the dominant players have changed significantly. Since 2007, vast changes have occurred in the hardware that is used to provide cellular communications. The trend was started with the commercial success of the iPhone, but has since grown exponentially due to three interrelated factors: network infrastructure investments, smartphone component improvements, and spectrum expansion. These three elements comprise a feedback loop for hardware investments and expansion:

![Diagram of Hardware Ecosystem Feedback Loop]

Figure 6: The Hardware Ecosystem Feedback Loop

Network Infrastructure/Operator Advancements:

A surging demand for smartphones has driven the need for more bandwidth through which companies can push more voice and data services. To accommodate this demand, the number of cellular tower sites has more than doubled, from just 127,540 sites in 2001, to
358,500 in 2011\textsuperscript{10}. As a consequence, the types of network transmission technologies operated by companies has expanded greatly, ranging from the older 2G/3G GSM and CDMA networks to the emerging 4G LTE, HSPA+, and WiMax options that are being deployed across the globe. In the old cellular model, the choices of the network carriers would have determined the technology that becomes predominant. Yet the flexibility of smartphone operating systems has allowed companies like Apple and Google to use all of the aforementioned wireless technology.

Of course, more options have created more pressure for wireless interoperability and compatibility. In order to meet this criteria, dozens of public/private working groups and technology standards committees have been created through the International Telecommunications Union (ITU-T) and its regional partners, which have developed over 160 recommendations for new network technology standards in 2007 alone. The work of these entities has codified the ITU's next-generation network (NGN) 4G standards, which strive to improve network speed, accuracy, stability, security, and global interoperability, while lowering deployment costs in developing markets\textsuperscript{11}.

**Device Hardware/Component Advancements**

The exponential advancements in network infrastructure have been driven by an unanticipated consumer demand for smartphone devices. In 2007, smartphones accounted for only 16.1 percent of devices sold, but in 2011 that number is estimated to reach 35.6 percent\textsuperscript{12}. Consumer demand has played a massive role in increasing the manufacturing output and has been responsible for component shortages, but companies have been eager to keep the sales momentum going.


However, handset manufacturers are also struggling to differentiate their products. As a consequence, companies have begun to include as many different sensors into their devices as possible. This trend is driving an unprecedented level of convergence between traditionally stand-alone technologies. In 2011, a high-end Android smart phone typically includes the following features: a front and rear-facing camera, gyroscope, digital compass, proximity sensor, accelerometer, light sensor, a Wi-Fi radio, GPS radio, and quad-band cellular radios - in addition to processors, touch-screen displays, graphics processing units, and flash memory. In 2005, consumers would be hard-pressed to find just one of these features in a cellular device, because most devices with advanced hardware were aimed directly at the enterprise or military markets.

Processors

Over the last three decades, Intel has been the dominant computer processor, graphics processing unit, and motherboard producer for the IT industry, for consumers, businesses, and governments. To achieve that ubiquity, Intel has ensured that its x86 processor architecture is used by the vast majority of computer integrators, suppliers, and software developers. Intel's most noteworthy partner has been Microsoft and both companies have benefited from their complementary and often bundled products. In Q4 2010, Intel commanded 80.8 percent of the overall processor market, while Microsoft controlled 89.6 percent of the operating system market by Q1 2011.

When the first Personal Digital Assistants (PDA's) reached the market in the late 1990's, Intel quickly formed partnerships with companies like Palm, RIM, and HP to supply them with low-power processors. Yet by 2007, the processing power of PDA devices had remained stagnant and Intel made no attempt to upgrade its technology. The introduction of the iPhone

changed that dynamic. While the iPhone’s cutting edge software design and its touch-screen
display drew the most praise from the press, its processor design choice was one of the biggest
hardware departures.

The ARM processor, used in the first iPhone, marked a breakthrough moment for ARM
Holdings, a company that has been developing mobile processor designs since the first
commercial PDA: the Apple Newton launched in 1990. ARM does not fabricate any chips on
wafers, but licenses its designs to companies that are interested in building and including those
processors into their own products. By 2007, ARM provided the designs for nearly ninety-eight
percent of the low-end cell phone processor market. The implementation of its high-end chips
into high-end smartphones essentially eliminated any foothold that Intel had, along with the PDA
market itself. Now, ARM’s chips have scaled from smartphones, to tablets, and even traditional
computers (as Microsoft has officially announced support for ARM in their next version of
Windows) - while Intel has yet to introduce a processor for smartphones. This change has
empowered a number of newer smartphone processor manufacturers, including Samsung,
Texas Instruments, Huawei, Qualcomm etc., leading to lower component costs for the final
products. In order to combat this trend, Intel is now partnering with handset manufacturers
from emerging markets, such as the Chinese company ZTE, to launch a test-run of its
smartphone processors by late 2011.

Despite the potential cost-savings that Apple realized from choosing ARM over Intel, the
components inside the original iPhone were of a significantly high cost, as the device retailed for
$700 USD off-contract. This premium pricing led to higher margins for both component
suppliers and integrators. Furthermore, Apple was designing its own smartphones, but was
outsourcing all of the production to Taiwanese and Chinese companies. This reliance on third-

17Ian King and Olga Kharel, "Intel Is Said to Design Phone for ZTE for Sale in China," Bloomberg, April 12, 2011,
party manufacturers proved to be completely contrary to the traditional model set by companies like Nokia and Motorola, which had been building and operating their own factories for decades. In 2008, Google took that approach a step further when it introduced the Android operating system and distributed it for free, without marketing, packaging, or selling any phone hardware.

Antennas

One of the premier assets of high-end phones is their data capabilities, which include Bluetooth, GPS, Wi-Fi, and at least one on-board radio for communicating with a carrier’s cellular towers. Network operators, which had traditionally campaigned directly against such connectivity in the early 2000's (out of the fear that Internet VoIP calling would replace standard calls) are now including these options as standard because non-cellular communications technologies are keeping their networks from getting overloaded by users. Furthermore, since wireless networks still have limited coverage across the majority of large countries, device manufacturers will be pressured to add more and more antennas, that can cover everything from 2G to 4G standards, on multiple frequencies. Some manufacturers have even gone so far as to offer “world phones”, that can operate on at least four different radio bands.

Capacitive Screens

Out of all of the features that smartphones introduced, perhaps the most defining one is the multi-touch screen. For the first time, users could directly interact with contextual elements on the screen, rather than relying on a mouse or a stylus. That not only changed the entire use experience, but altered both hardware and software development paradigms. Multi-touch tablet surfaces had been sold as enterprise devices since 1985, but they were not directly integrated with displays. In 2001, Mitsubishi began to produce these devices at a large scale and Apple became the first computer company to miniaturize it for handheld use.

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Smartphones not only brought the technology out of obscurity but made it a necessity. Out of all of the technologies listed and assessed in this report, the multi-touch screen is the only component that needs the physical input from the human body to function. The screens themselves include capacitive sensors that both transmit and receive electrical signals. The electrical current conducted by the human skin creates the contact that is registered by the screen, which instantly rendered all other input types obsolete.\textsuperscript{19}

**Mobile Spectrum Expansion**

The growing number of advance networks and smartphones will not be enough to ensure a compelling Internet experience. Mobile carriers must find enough radio/electromagnetic spectrum to transmit more data between their networks and devices. Spectrum frequencies are used as communications channels between devices, which was the model used by analog televisions to stream channels for decades. Traditionally, governments have controlled ownership rights over their domestic spectrum allocations and hold auctions or license out the use of that resource to private entities. Spectrum management allows nations to dictate how telecommunications services emerge within their borders and whether or not there will be interoperability between different carriers.

Now, smartphones have compelled governments to accelerate the pace at which public spectrum is distributed to network operators, and those companies are willing to pay billions of dollars for just a fraction of that resource. This marks for governments, which have traditionally allocated more spectrum for television, radio, and defense purposes, but are now seeing cellular markets as an opportunity to connect citizens in rural areas.

In 2010, the United States's executive branch issued a memorandum guaranteeing that the National Telecommunications Administration would free up 500 MHz in federal and non-federal spectrum over the next ten years, which will be licensed out by the FCC for developing

commercial and non-commercial broadband\textsuperscript{20}. Simultaneously, the Obama administration has initiated a process by which the federal government would create a national cellular network specifically for first-responders and emergency personnel. That infrastructure and complementary devices would follow the framework set by private companies that have been deploying smartphones.

Currently the European Union follows a more decentralized model, as spectrum licensing and numbering are processed individually by member states. The European Commission’s “A Digital Agenda for Europe” program outlines an EU plan to expand universal broadband access to 100 percent of consumers by 2020. The Commission estimates that inefficiencies in spectrum-usage cost both governments and companies almost 250 billion euro annually. The solution will be to enact new policies that mandate the use of specific digital frequencies for wireless broadband, promote efficient spectrum management, and create a market for trading spectrum allocations (similar to the carbon trading market)\textsuperscript{21}. These proposals are going through approval procedures, even as EU countries are pressing forward with their 4G spectrum auctions in 2011.

The Canadian government is also planning an auction for this year, as it is planning to free up 700 MHz of spectrum to facilitate the deployment of 4G services. The Ministry of Industry is using this auction as an opportunity to assist smaller network operators and is weighing the options of leaving out large incumbents who already have sufficient spectrum\textsuperscript{22}.

Overall, the shifts in hardware policies, practices, and technologies have occurred in a synchronized fashion, which has been accelerated by the success of smartphones. This type of coordinated change would not have been possible in the 1980s or 1990s, when cellular markets


and technologies moved to the tune of their regional politics and standardization practices. In
the next section, we will explore how software development for phones has evolved along a
similar path, while incorporating elements of the IT industry.

IV. The Software Transition

In the 1990s, the majority of cellular phones could perform only a few functions - send
calls, receive calls, store addresses, etc. Now, smartphones can access hundreds of thousands
of applications, each of which has unique capabilities. That turning point in cellular software
was triggered by the introduction of the iPhone in 2007. At the time, the New York Times stated
that “the iPhone is the most sophisticated, outlook-challenging piece of electronics to come
along in years... But the bigger achievement is the software.”

The impact of software, however, goes beyond merely enabling smartphones to drive
down the value proposition of lower-end devices that are not smartphones. The proliferation of
software has also given consumers new reasons to discriminate between mobile operators.
This section discusses how advances in smartphone software since 2007 have allowed some
companies to advance, while others have failed to maintain parity. Some companies who had
driven the software trends until that point, like Nokia, have lost ground, while newcomers like
Google are quickly accelerating.23 24

The Disruptive Rise of Third-Party Applications.

One of the primary advantages of smartphone operating systems is that they can run
complex third-party-developed applications. This software can dramatically enhance the user
experience and allow for high levels of customization. Procurement of applications is handled
directly through on-board vendor marketplaces, which process digital transactions. Apple’s

“App Store” contains over 350,000 apps, Google’s “Android Market” has over 150,000 apps,

and Nokia's "Ovi Store" has 35,000 apps. Figure 7 shows market growth and revenue for each application store.

Providing users with access to diverse applications has become critical element of success in the smartphone market. In fact, Apple's App Store has experienced such a positive response from both consumers and developers that the same digital distribution model is being expanded to Macintosh computers. The popularity of applications on Apple's iPhone prompted the Wall Street Journal to create a focus group of individuals that would switch to the device and provide feedback. The conclusion from this test was that "the experience of using apps on the iPhone—and the huge selection of apps in the App Store—significantly enhance Apple's device."

The importance of software for smartphones parallels how Windows software directly drove the sales of personal computers in the 1990s. Eric Roberts, a Professor from Stanford University noted that, "soon after Windows 3.0 was released, Microsoft released Excel 3.0 for Windows and Word for Windows 2.0. These products received great reviews and became the top sellers of their categories, surpassing Lotus 1-2-3 and Word Perfect, which were still mired in DOS." As a result "Windows 3.1 became the operating system on over 70 percent of personal computers." That example is directly analogous to the revenue impact of applications on smartphone devices.

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26 Chart below (Figure 7) was created by author using statistics taken from: Daniel E. Dilger, "Apple's rivals battle for iOS scraps as app market sales grow to $2.2 billion," Apple Insider, April 17, 2011, http://www.appleinsider.com/articles/11/02/18/rim_nokia_and_googles_android_battle_for_apple's_ios_scraps_as_app_market_sales_grow_to_2_2_billion.html.


Applications have also become critical for consumers. Recognizing this companies have adopted different strategies to attract applications into their marketplaces, in order to monetize those products. Apple's App Store operates on 70-30 split, where 70 percent of the money goes to app developers and 30 percent goes directly to Apple. Google uses a different approach for the Android Market, as 30 percent of application proceeds go directly to the network operators. Google estimates that the resulting boost in usage would outweigh any lost revenue. Only time will tell which strategy will be more successful in the market.

The Shift From Proprietary to Open-Source Software

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30 Chart below (Figure 7) was created by author using statistics taken from: Daniel E. Dilger, “Apple's rivals battle for iOS scraps as app market sales grow to $2.2 billion,” *Apple Insider*, April 17, 2011, [http://www.appleinsider.com/articles/11/02/18/rim_nokia_and_googles_android_battle_for_apples_ios_scraps_as_app_market_sales_grow_to_2_2_billion.html](http://www.appleinsider.com/articles/11/02/18/rim_nokia_and_googles_android_battle_for_apples_ios_scraps_as_app_market_sales_grow_to_2_2_billion.html).


The free nature of open-source operating systems has enabled multiple manufacturers to produce handsets using one software platform. This is exemplified by the Open Handset Alliance, a project initiated by Google to add private sector software contributions to Android, which now includes manufacturers like HTC, Motorola, and Samsung. Android contrasts with other OS’ because its code can be used and edited freely by third parties. Apple’s iOS and Nokia’s Symbian were proprietary from the outset, as both companies were concerned with the loss of their intellectual property. By 2011 Android surpassed Symbian as the world’s highest-selling platform for smartphones.\(^{36}\)\(^{37}\) The open-source nature of Android expanded the number of hardware vendors developing high-end phones, but none of those companies have acquired a dominant sales position\(^{38}\)\(^{39}\).

![Handset Manufacturer Operating System Share for Smartphones](image)

\textit{Figure 8: Handset Manufacturer Operating System Share for Smartphones}\(^{40}\)

\(^{36}\)The Open Handset Alliance, \url{http://www.openhandsetalliance.com/}.


\(^{38}\)“Who is Winning the U.S. Smartphone Battle?” Nielsen Wire, March 3, 2011, \url{http://blog.nielsen.com/nielsenwire/online_mobile/who-is-winning-the-u-s-smartphone-battle/}.


\(^{40}\)“Who is Winning the U.S. Smartphone Battle?,” Nielsen Wire, March 3, 2011, \url{http://blog.nielsen.com/nielsenwire/online_mobile/who-is-winning-the-u-s-smartphone-battle/}.
This type of diversity fosters more competition between Android manufacturers, encouraging them to create better software and hardware features, which only adds more choices to the market. This contrasts directly with situations in which companies vertically control both their hardware and software, such as Apple’s iOS or the RIM’s Blackberry OS. Product diversification can also act as a safeguard against hardware defects. For example, when Apple’s iPhone 4 was introduced, it immediately experienced signal attenuation issues with its antenna, and its users were forced to wait for Apple to deliver a software solution. If a particular Android phone suffered from similar issues, users could immediately return the device to their mobile carrier and replace it with a different model while retaining the same software.\footnote{Manufacturers like HTC have taken that flexibility a step further by allowing users to completely replace the entire Android operating system on their devices with a customized version of their own choosing.}

The competition between proprietary and open-source smartphone operating systems can be visualized through the Herfindahl Index. The index scales all the way from a high of 10,000 points, which means no competition, to a low of 0, which symbolizes high diversity. The formula for the Herfindahl index is \( H = \sum_{i=1}^{n} s_i^2 \), where each \( s \) represents the market share of the firm. If two firms each have 50% of the market, \( H = (50)^2 + (50)^2 = 5000 \), for instance.

The Herfindahl index depends on how the market or markets are defined. If we define each “operating system market ecosystem” to be the manufacturers using a certain operating system ecosystem, we can calculate the figures below, sorted by decreasing value of \( H \):

\begin{center}
\begin{tabular}{|c|c|c|}
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\textbf{OS Ecosystem} & \textbf{Herfindahl Index (lower number means more diversity)} & \textbf{Closed, Licensed, or Open?} \\
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<td>iOS</td>
<td>H=10,000</td>
<td>Closed Ecosystem</td>
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<tr>
<td>Blackberry</td>
<td>H=10,000</td>
<td>Closed Ecosystem</td>
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<tr>
<td>Symbian</td>
<td>H=~10,000</td>
<td>Closed Ecosystem</td>
</tr>
<tr>
<td>Windows Mobile/Phone</td>
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<tr>
<td>Android</td>
<td>H=3,250</td>
<td>Open-Source Ecosystem</td>
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In the above table, we see that the numbers confirm our intuition - the second and third columns are correlated. The Herfindahl index for smartphone software vendors demonstrates that open-source models lead to the most competition, while closed approaches are far more restrictive.\(^{43}\)

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**Smartphone Software Security Concerns**

In 2007, an Information Week survey polled readers about which "software features are most important when considering smartphones for business use," and found that "security" tied for first place, significantly ahead of "wi-fi support" or "multimedia." The interconnected nature of smart devices is affecting corporate purchasing decisions, especially when poor security could negatively impact the company's sales or intellectual property.\(^{47}\)

The availability of third-party applications only further exacerbates this issue. According to CNET, "one of the major reasons why smartphones are such a strong potential target for hacking is due to the large quantity of applications developed by so-called "third parties.""\(^{48}\)

Smartphone security is not only a problem on user's devices but in the "cloud" well, since the

\(^{44}\) Tony Bradley, "Consumer Reports Reiterates Caution Against iPhone 4," PCWorld, [http://www.pcmag.com/businesscenter/article/205415/consumer_reports_reiterates_caution_against_iphone_4.html](http://www.pcmag.com/businesscenter/article/205415/consumer_reports_reiterates_caution_against_iphone_4.html).
increased use of online services has pushed more personal information on corporate servers. RIM's Blackberry platform has addressed this issue by encrypting communication data between servers and devices - which has been an attractive feature for both businesses and governments. However, this closed system has created problems for RIM, as India, Saudi Arabia, and the United Arab Emirates have sought access to encrypted BlackBerry data, stating that encrypted e-mails posed a risk to national security. It is still unclear how customers perceive the security of different smartphone operating systems, but they may be reluctant to trust business that allow personal information to be compromised.

Persistently-Connected Applications

One key element of any smartphone platform is offering robust web browsing. Consumers now make use of "persistently connected apps" that are continually connected to the Internet. This dynamic software also changes people's usage of smartphones over time, while people with cheaper devices are often limited to calling and text messaging. The ability to use the Internet on a cellular devices creates an interesting business situation for phone manufacturers and carriers, because it creates new revenue streams from software (i.e. advertising, in-app payment systems etc.) The Silicon-Valley Mercury News noted that, "For each one percent shift in U.S. search traffic from desktops to mobile devices, Google gains $50 million in ad revenue..." This revenue is captured by Google, even if the provider of the phone is another company, such as Apple's iPhone, which includes Google's "persistently connected apps." However, other forms of transaction systems can be added to smartphones over time.

while traditional phones are limited to a number of premium applications that are pre-determined by the network operators.\textsuperscript{52} \textsuperscript{53}

**Fragmentation of Software Development Languages**

The proliferation of smartphones presents drawbacks in addition to new opportunities for software developers. An article in *IEEE Spectrum* noted that, "Desktop programmers have it easy. Most can still program for 90 percent of the market—Windows... For smartphones, though, things are different because of the market's heterogeneity... if you want to reach even 70 percent of the market, you have to program for more than one environment." Companies building third-party applications take advantage of software development kits (SDK), which vary based on the software vendor. Each SDK uses a different programming language - Android uses Java as the programming language, iOS uses Objective-C, Symbian uses Qt and C++ etc. Creating applications for multiple platforms often entails months of employee training or investments in new human capital.

The issue of the SDK is amplified by the lack of industry standards in this field as there currently is no software language that can be used by every smartphone\textsuperscript{54} \textsuperscript{55}. Statistics aggregated by Tiobe Software—a coding standards company—showed that the introduction of the iPhone increased the usage of Objective-C amongst developers for mobile, but its popularity is still dwarfed by a number of older web and computer languages. The variety of languages has a key impact on the smartphone industry because apps must be modified for every device.

Overall, SDKs offer a new challenge and opportunity for developers, but there is plenty of room for standardization. Overall smartphones have been driving advances in software since the introduction of the iPhone four years ago, causing major changes in market positions -- demoting some companies and advancing others. Software on smartphones has not only driven down the value of normal cellular devices, but it has given consumers strong incentives to choose between software and hardware vendors. In this type of market, companies that are slow to innovate will continue to see their market share decline.

V. Business Factors and Models

The prior sections have demonstrated the intense rivalries between the telecommunications companies that are driving smartphone sales. Differentiation is difficult to achieve due to the sheer number of devices in the market and companies have been pressed to innovate their business strategies in order to capture additional value. Incumbents like Nokia have focused on streamlining their supply chains and producing hardware that can appeal to both developing and developed markets. Meanwhile, Apple and Google have used application payments and advertising to bolster their developer appeal and earnings. Yet companies like Intel and Microsoft have been constrained by legacy business practices, that have restricted them from succeeding in the smartphone business.

Value Chain

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60 Martin Kenney and Bryan Pan, “Structuring the Smartphone Industry: Is the mobile Internet OS platform the key?” Keskusteluaiheita discussion paper, (February 2011).
The process of creating, selling, and supporting cellular devices can be conceptualized as a sequential value chain or ecosystem. The hardware and software components used by the manufacturers of devices are often invisible to end-users. The elements of the chain that consumers come into direct contact with are device provision and network access. The addition of content, as a critical part of the value chain, has augmented the overall value of each device sold.

![Figure 10: Value Chain in Smartphone Industry](image)

At the turn of the last decade, the cellular phone market was saturated with commodity devices, that offer a low cost of entry to customers and minimal revenues to manufacturers. Handset producers and network operators competed in a "zero-sum battle" for market share. Competing on price was the most efficient way to gain access to new markets, but it attracted both new customers and new competitors from South Korea and China. The introduction of the iPhone changed the sales strategy discussions from price-focused to feature-centric. This allowed Apple to circumvent an increasingly saturated phone market and offer high-priced devices with sophisticated computing features.

**Product Differentiation**

Any successful business model requires that firms generally sustain value in the face of competition. In order to achieve this goal, some cellular device companies have attempted to cut down their product lines while others have significantly expand the total number of devices that they sell in the market. Nokia's former CEO, Olli-Pekka Kallasvuo, commented that his

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company needed "to have 40-plus devices out" at any given time, in order to "tackle every part of the market." This strategy led directly "to high market share" because "one size will not fit all for mobile communications." Android manufacturers have adopted the same approach by releasing dozens of devices per year and increasing the overall speed of hardware evolution and obsolescence. Some analysts believe that product differentiation will allow firms to capture more of the smartphone market, but it can also stress their resources and lower the overall attention to detail given to each smartphone. Companies also fear that the too many devices can create inflation in the market and lower the overall prices that both manufacturers and carriers can charge. On the other end of the spectrum is Apple, which releases only one smartphone per year. This allows the company to focus its marketing and sales assets on a single product while continuing to charge a premium price.

**Manufacturing Practices and Costs**

The production of smartphones is handled almost exclusively in China and Taiwan for all of the aforementioned companies, but the types of outsourcing can vary. Nokia is one of the only corporations that attempts to control every portion of the value ecosystem, from manufacturing device components to developing applications, while shipping products in over 150 countries. Nokia operates all of its global manufacturing facilities and attempts to leverage its economies of scale to drive down costs. Meanwhile, other companies have almost exclusively focused on hardware development rather than creating their own software. This makes them a good match for a company like Google, which does not have any manufacturing operations of its own. Google relies instead on licensing its applications and freely distributing its operating system to increase the company's overall market penetration. Apple follows an altogether different approach by outsourcing manufacturing and assembly but directly

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controlling almost everything else, including "intellectual property, product design, system integration", cost management, and customer service.

The actual cost of manufacturing smartphones is relatively equal across all of the companies listed and typically ranges from $183-$196 for hardware and assembly. However, firms often prioritize certain types of components over others. For the iPhone 4, Apple paid more for the device’s memory and aluminum housing than any other manufacturer spent on any individual component. Jony Ive, Apple’s Senior Vice President of Design, attempted to explain these figures by stating that, “the quality of the materials, the manufacturing precision and advanced technology, ultimately all of this becomes relevant when you hold it in your hand.”

**Figure 11: Sampling of Device Manufacturing Costs**

<table>
<thead>
<tr>
<th>Device</th>
<th>Retail Price</th>
<th>Manufacturing Cost</th>
<th>Profit</th>
<th>Profit/Price %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone 4</td>
<td>$599-$649</td>
<td>$194.05</td>
<td>$404.95</td>
<td>67.60%</td>
</tr>
<tr>
<td>Google Nexus One</td>
<td>$529</td>
<td>$191.65</td>
<td>$337.35</td>
<td>63.77%</td>
</tr>
<tr>
<td>Nokia N8</td>
<td>$519</td>
<td>$196.96</td>
<td>$322.04</td>
<td>62.05%</td>
</tr>
</tbody>
</table>

*Retail price is listed for no-contract device. Profit is estimated including materials/assembly only. The profit does not take into account shipping, advertising, R&D, licensing, IP royalties.

The iPhone is not “made in China,” but it is assembled there with components imported from many other countries including: 34 percent from Japan, 18 percent from Germany, 13 percent from South Korea, six percent from U.S., three percent from China, and 27 percent from other nations. The cost of assembly amounts to only seven percent of the overall cost. The Chinese market is also far less attractive than in the past as wages have risen over 50 percent.

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64 Jason Dedrick, Kenneth Kraemer, and Greg Linden, “The Distribution of Value in the Mobile Phone Supply Chain,” Personal Computing Industry Center, October 2010.

65 Martin Kenney and Bryan Pon, “Structuring the Smartphone Industry: Is the mobile Internet OS platform the key?” (Keskusteluaiheita discussion paper, February 2011).


since 2005, and companies have struggled to maintain their low costs. Despite the rising assembly costs, manufacturing for the iPhone 4 was 36 dollars less than the original iPhone, which has allowed Apple to make more profit per unit.

The average selling price (ASP) for smartphones is also a leading indicator for each company's value. ASP represents the unsubsidized cost paid by network operators, which is minimized for consumers with fixed-term contracts. Over the past three years, the large telecom incumbents have experience erosion in their ASP. Nokia's price fell from $114 in 2007 to $80 in 2010. Apple's pricing currently is the highest in the industry, averaging $635 in 2010.

![Figure 12: Average Selling Price, Operating Margin, and Profit Share for Q2 2010](image)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Nokia</th>
<th>Nokia SP</th>
<th>Samsung</th>
<th>LG</th>
<th>SE</th>
<th>Motorola</th>
<th>RIM</th>
<th>Apple</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.S.P.</td>
<td>$80</td>
<td>$181</td>
<td>$110</td>
<td>$125</td>
<td>$210</td>
<td>$215</td>
<td>$295</td>
<td>$635</td>
</tr>
<tr>
<td>O.M.</td>
<td>12%</td>
<td>-</td>
<td>7%</td>
<td>-4%</td>
<td>1%</td>
<td>5%</td>
<td>25%</td>
<td>45%</td>
</tr>
<tr>
<td>Profit share</td>
<td>22%</td>
<td>-</td>
<td>10%</td>
<td>&lt;1%</td>
<td>1%</td>
<td>2%</td>
<td>17%</td>
<td>48%</td>
</tr>
</tbody>
</table>

Nokia, Motorola, Sony Ericsson, LG, and Samsung collectively have an average operating margin of 4.5 percent, down from 8.6 percent in 2007. In contrast, RIM and Apple have an average operating margin of 34 percent, up from 24 percent in the same time frame.

In other words, profitability has shifted to a different subset of companies in the smartphone industry. This trend also explains why handset manufacturers like Samsung, LG, Motorola, etc. have been eager to incorporate Android into their devices to remain competitive in spite of the changing landscape.

**Network Providers**

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The smartphone supply chain is directly influenced by network operators, which play a prominent role in handset choices, product sales, marketing, pricing, and customer engagement. In Europe and the United States, carriers subsidize the cost of high-end handsets for customers in exchange for a fixed-term usage contract. This subsidy has allowed manufacturers to set lower prices aimed directly at the average consumer. Subsidies allow Apple to sell its iPhone 4 for only $199 to the customer, while still receiving a full payment of $649 from the network provider.\textsuperscript{72} Since handset manufacturers still receive full price for the sale, their operating earnings will remain high, along with their overall sales volumes.

The psychological effect of subsidized prices distorts the decision-making process of consumers. In addition, subsidies create a high barrier of entry for firms that want to sell smartphones directly to customers that are not locked down to a single operator.\textsuperscript{73} For example, in the United States, where the iPhone is subsidized and the Nokia N97 is not, the iPhone outsells the N97. Yet in the United Kingdom, where the N97 is free, it outsells the iPhone. Therefore, carrier subsidies play a direct role in the success of any smartphone.

Subsidies are a minimal price for operators to pay, because they find significantly more value from consumer data plans over the course of a contract. Based on the average monthly plan of $84.99 for an AT&T iPhone 4 and $217 for the device and activation fee, the total cost of an iPhone with a two-year contract would be $2257 before taxes and miscellaneous fees.


\textsuperscript{73} Martin Kenney and Bryan Pon, "Structuring the Smartphone Industry: Is the mobile Internet OS platform the key?" (Keskusteluaihetta discussion paper, February 2011).
Table 3: Price Plan Comparison, 2011 vs 2009 (Price per Month)

<table>
<thead>
<tr>
<th>Network</th>
<th>Sprint</th>
<th>T-Mobile</th>
<th>AT&amp;T</th>
<th>Verizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheapest bundle with unlimited text and data, 2011</td>
<td>$79.99 450, unlimited data, text</td>
<td>$79.99 500, unlimited data, text</td>
<td>$84.99 450, unlimited data, 2GB data</td>
<td>$89.98 450, unlimited data, text</td>
</tr>
<tr>
<td>Cheapest bundle with unlimited text and data, 2009</td>
<td>$69.99 450, unlimited data, text</td>
<td>$59.98 300, unlimited data, intro text</td>
<td>$74.99 450, unlimited data, intro text</td>
<td>$74.98 450, unlimited data, intro text</td>
</tr>
</tbody>
</table>

Much of the profits that network operators earn from subscription plans are reinvested into next generation network infrastructure. A report from industry analyst Yankee Group, suggests that carriers offering the iPhone do not turn a profit on the subscriber until month 17 of a 24-month contract, due to increased data usage by consumers, spectrum scarcity, and cell tower upgrades, which are believed to be costing the industry $50 billion a year. In response, wireless carriers are raising the prices for mobile phone subscriptions. Verizon and AT&T have ended exclusive discounts for renewing customers and have increased overage charges. Since 2010, a number of carriers in the United States restructured their plans to include tiered pricing for data usage. AT&T removed its $25 unlimited smartphone data plan in June 2010 in favor of two tiered options: $15 for 200MB and $25 for 2 GB. Verizon has followed suit and capped its previously unlimited data plan to 5 GB. In addition, Sprint recently decided to implement a premium $10 monthly data add-on for newer 4G services. William Stofega, director at IDC, stated that, “wireless is a capital-intensive business, and carriers need to figure out ways to make money.”

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77 David Goldman, “Your mobile phone bill is going up,” CNN Money, January 20, 2011.
User Practices and Markets

Companies are shifting their resources towards more applications, services, and usability, which means a greater focus on user preferences. While Nokia and Microsoft have spent decades attempting to create innovative technologies, the original iPhone succeeded by creating a visually-appealing user experience. Consumer experiences now play a predominant role in the adoption and diffusion of smartphones. This also means that grassroots Internet advertising that caters to specialized segments of the population is now becoming more effective than expensive television marketing. This is partly due to the fact that many consumers are unfamiliar with cellular device specifications, when purchasing their first smartphone. Instead, they are focusing more on the product platform and brand reputation when making mobile decisions.\(^{78}\)

In fact, users are the most concerned with gaining access to the Internet. Applications must be effective at replicating the traditional Internet computing experience on a phone, but it seems that they are not currently meeting expectations. The most widely used cellular services: voice, SMS, and calendaring receive high satisfaction and high usage. Web browsing, email, and map applications receive moderate satisfaction ratings and usage usage. Meanwhile, games, VoIP, and instant messaging receive low usage and low satisfaction.\(^{79}\) The companies that can best meet user preferences with their products, will be the most likely to succeed in the market. Companies like Nokia are trying to refocus from value-engineering their products to providing better user experiences.\(^{80}\)

Apple and Google have been successful in appealing to individuals who are purchasing smartphones for personal use. In particular, Apple has succeeded in gaining loyalty from


individuals 25-35 years of age, college educated, and with an income of greater than $100,000. Customer satisfaction and hype plays a major role in the success or failure of any device. Almost 80 percent of customers are "very satisfied" with the Apple iPhone, while only 30 percent of customers are satisfied with Nokia's smartphones.

Smartphone competition is still in its early stages and companies are learning how to adapt. Currently, a dominant design for a business model has not emerged, but the trends are becoming clearer: more choices, cheaper devices, more expensive services, and an increased focus on users. Collectively, there is more money being made by smartphone companies due to the high demand rather than innovative business practices. Therefore, it is possible that new entrants could succeed in developing innovative methods for earning revenue from smartphones that could threaten all existing incumbents and undermine their business models.

VI. The External Market Impact of Smartphone Growth

Incumbent cellular companies and wireless operators are directly impacted by the diffusion of smartphones into society, and many of these companies have dramatically changed their business model—including their target market, operations, and product line—to survive this technology transition. Not surprisingly external industries, like GPS suppliers and the medical field, are also affected by, and are reacting to, the smartphone transition. The medical field is utilizing smartphone technology as it is increasingly adopted by society to improve the experiences of doctors and their patients. Although the competition from the smartphone market alone has yet to bankrupt any multinational corporations in related or external industries, the popularity of such devices is increasing the pressure on many companies to change their product lines and services.

The adoption of smartphones has significantly impacted GPS suppliers—like TomTom and Garmin—which faced little to no competition prior to 2009. Both of these companies projected heavy losses for 2011 as the market for their core products is expected to shrink by almost 15 percent. The proliferation of GPS receivers and mapping services, which will be pre-installed on nearly 75 percent of smartphones in 2011, have given consumers a free alternative to Garmin and TomTom’s products. Location-based services (LBS)—a combination of GPS and smartphone applications—is a growing market, and this concept is particularly difficult for GPS suppliers to duplicate using their current devices. Roughly 40 percent of smartphone users have adopted LBS as part of their smartphone experience, creating a new, growing niche for businesses to market. The proliferation of LBS on smartphones, particularly when combined with social networking, introduces real-time customer feedback and essentially free advertising to businesses that participate in the market. Instead of only retrenching into their current market to survive, companies like Garmin and TomTom have shifted their product line to include built-in car navigation systems, live traffic services, and recreational/athletic GPS devices to target both new and existing customers. This relocation to a new market—meaning either targeting a current set of problems for new customers or a new problem of its current customers—could be successfully implemented by Garmin and TomTom if they use this new market opportunity to gain their financial footing and continue innovating in more promising areas in the future.

Personal digital camera manufacturers are feeling similar pressures in the mass market as sales of their consumer devices declined nearly five percent in 2010. Smartphones have

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85 Dan Butcher, "Forty Percent of Smartphone Users Have Adopted Location-Based Services," Mobile Commerce Daily, 2011/04/19/forty-percent-of-smartphone-users-have-adopted-location-based-services.
become the de facto competitor for the camera industry, because much of the same core functionality is included as standard on even low-end cellular devices. Instead of cutting the prices of their products, camera companies are attempting to add new features to their devices—such as Wi-Fi connectivity and social networking options, both of which helped popularize the original iPhone in 2007. This time lag for feature introductions in digital cameras will only be exacerbated in 2011 by the introduction of 3D photo/video capture phones launched at current smartphone price levels.\textsuperscript{88}

Many of the markets that have yet to be impacted by smartphones are specialized and remote, such as commercial fishing, aerospace, etc. In these particular markets the smartphone is less desirable, because the lack of cellular signals limits connectivity to GPS signals. Similarly, citizens in developing countries without widespread 2G/3G/4G wireless infrastructure will not purchase a high volume of smartphones, because consumers will simply not be able to take advantage of advanced services without a modern network.

Tangent markets, such as health care, that currently do not involve the widespread use of smartphone technology are likely to be affected by this or similar devices in the near future. With recent U.S. policy trends aiming to convert patient information into digital medical records, the health care field and smartphone markets are beginning to intersect. According to Manhattan Research, the number of physicians who own a smartphone will increase from 64 percent in 2009 to 81 percent by 2012. According to an MDsearch survey, among the physicians who own smartphones, there are twice as many iPhone users as there are Blackberry users\textsuperscript{89}. Considering the projected growth in the medical smartphone market, those companies in a position to do so should quickly begin to target this opportunity.

\textsuperscript{88} Ross Rubin, "Can Digicam's Survive in the Smartphone Age?" CNET, March 29, 2011, \url{http://news.cnet.com/8301-17938_105-20048415-1.html}

\textsuperscript{89} "Are Physicians Using Smartphones?", My Telecom Info, November 3, 2010, \url{http://www.mytelecominfo.com/are-physicians-using-smartphones/}
Epocrates, a popular application among physicians, gives doctors information on possible drug interactions, side effects, health insurance coverage, etc. Medical references have also become popular smartphone apps for medical students, which could rapidly increase the pace of the smartphone transition into the medical field as these students begin practicing medicine. The line between desktop or laptop computer use and smartphone use by doctors in their practice is blurring, and internet-based diagnostic tools are more becoming more widespread in their use and availability.

Smartphone applications are offered for an increasing variety of categories, including general diagnostics, laboratory results, digital imaging, instant electrocardiogram results and interpretations, obstetrics monitoring tools, remote physician consultation, electronic prescription systems, and medical records. All of these indicators point to an increasing diffusion rate of smartphones into the medical field; however, several factors might slow this trend. Some of the applications are poorly conceived and do not target those individuals that are likely to use this technology. The transparency level of the medical apps' designers, for example pharmaceutical companies that design applications promoting their drugs in subtle ways, might also affect the pace of diffusion. Another concern involves the credibility of the medical app itself. Without some level of oversight, the situation could get out of hand as these medical applications are not a substitute for a real doctor\textsuperscript{30} and should be independently evaluated for accuracy. Even with these concerns, the diffusion of the smartphone into the medical profession seems inevitable, and the incumbents and new entrants to the smartphone market should set their eyes on this new, exploitable, high-growth potential market.

VII. Conclusion

"Nokia, our platform is burning"

- Nokia CEO Steven Elop, February 8, 2011 91

The quote above is an excellent reflection of the fast-moving pace of the smartphone market and the associated technology transition. Nokia - a widely acknowledged market leader just a few years before - was unable to keep up with innovations introduced by competitors, leading to a drop in Nokia's market share and dramatic words from Nokia's new CEO. In order to understand the transitions in the smartphone industry and its impact on the market, this analysis examined a wide variety of issues including theoretical and sociotechnological models for technology transition and disruptive innovations, changes in hardware development and how they drove the adoption and growth of smartphones, how the proliferation of diverse software allowed firms to differentiate their smartphone products, changes in corporate factors such as pricing models, the value chain, and user behavior, and the impact on adjacent technology fields like the medical field.

This paper provides numerous insights that are helpful for understanding the smartphone transition and its place in the larger theory of technology transition. By applying the theory of incumbents vs. new entrants, and combining them with sociotechnical elements (users, software, hardware, wireless operators, etc.), we can start to understand why some firms, such as Nokia, saw precipitous declines in market share, while other firms, like Apple and Google, were able to either capture or create new market share. The hardware ecosystem has seen a positive feedback loop, reinforced by smartphones, that has led to massive changes in capability, connectivity, and spectrum availability. New entrants and incumbents alike have scrambled to develop new software that can capture revenue streams, attract users, and

increase profit. And because the corporate factors of the smartphone market indicate that this market is fast-changing with rapid turnover, a firm that is the leader today cannot be assured of dominance in a few years' time.

The smartphone industry serves as an excellent case study of how general theory on technology disruption, combined with a detailed "on the ground" analysis of the hardware, software, and corporate factors involved, can be applied to explain rather dramatic shifts in a multi-competitor field. The bottom line is that in just a few years smartphones have seen wide adoption, displaced market leaders, created new policy and business challenges, and offered empirical data that improves our understanding of technology transitions.