Google's affair with Open Source Software:

From browser wars to mobile domination

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Daily communication is facilitated by digital technologies through Web sites and social media, and accessed via computers and mobile devices (Meeker, Devitt, & Wu, 2009). The computer has "transformed the way we live, work and play" (Lunenfeld, 2011, p. 143). Communication devices are driving the development of technology standards that are very powerful for consumers, but even more powerful and profitable for the companies that control them. A battle continues for control over the way we access information online via Web browsers on computers and mobile devices. The owner of the most popular interface has an advantage because it can influence how the public sees information, favouring some content over others. But more importantly, it profits from selling access to these viewers to advertisers and it can choose who it will allow to advertise and who it will block.

Google is an Internet services and software company that maintains an index of Web sites for users and sells online advertisements. With a clean and efficient interface backed by an impressive array of online tools, Google exploits every unique aspect of the medium to harvest individual social behaviour (Langlois, McKelvey, Elmer, & Werbin, 2009; Milberry & Anderson, 2009; Van Dijck, 2009), serving targeted ads on a wide variety of web pages and within personal email. However, no ads appear on pages in the google.com domains giving Google a non-commercial Web presence. It evades appearing as one of the world's largest and most powerful advertising companies, one which controls much of our online experience. Its revenues of $37.9 billion US in 2011 come from programs such as AdWords, an auction-based advertising program; AdSense, which enables Web sites that are part of the Google Network to deliver ads from its AdWords advertisers; Google Display; DoubleClick Ad Exchange; and YouTube (Bloomberg, 2012). But access to users via Web browsers like Firefox is not free for Google. The company has contracted to pay Mozilla, makers of the Firefox browser, $300

million per year over the next three years for driving traffic to Google ads (Gilbertson, 2011). Other browsers, like Microsoft's Internet Explorer (IE), have limited Google's access to users by favouring their own ad networks (Waters, 2008).

The Web browser is the primary interface that mediates our access to online information, and it is rapidly shifting to the mobile Web which is predicted to outpace desktop Web usage by 2015 (Morgan Stanley, 2009). While Web browsers and operating systems do not limit the mobility of users nor force them to use only one search engine, they do have a strong influence in suggesting content, and most users accept the default setting without question (Vaidhyanathan, 2011). With staggering profits at stake, owning the dominant browser or operating system is very desirable. Early competitors for network control closely guarded their intellectual property. But late entrants like Google are increasingly choosing to make its software open source and share their intellectual property in order to gain direct access to these networks.

Open Source Software (OSS) is a "method of managing and distributing software that permits users to study, change, improve and at times distribute the source code, depending on the type of license granted with the software" (Open Source Initiative, n.d.b). Proprietary software companies like Microsoft are generally opposed to OSS because they profit by restricting access (Greene, 2001). Software is developed using a computer language that humans can read, like C+ or Java, and then compiled into binary machine language, a very long series of ones and zeros, for the computer to execute. Proprietary software is distributed as binary, making it virtually impossible for users to understand how the program works or to make modifications to it; whereas, OSS makes the higher level language accessible to the user.

OSS played a major role in the battle to protect open standards on the Web. During the first browser war, the established standard, Netscape Communicator, was defeated by Microsoft's Internet

Explorer (IE) (Bresnahan & Yin, 2006; Cusumano & Yoffie, 1998; Sebenius, 2002). With control over 95% of the browser market in 2004, Microsoft had a powerful advantage over other companies, controlling how both citizens and corporations could access and interact with the Web (Oshri, de Vries, & de Vries, 2008). That was until Mozilla Firefox, an OSS product, grew in popularity between 2004 and 2007, claiming over 20% of IE's market share, threatening its standard. There is a rich analysis of both browser wars in the academic literature, however little has been published since Google launched Chrome on September 1, 2008.

OSS has received wide attention in business, media and academia because of its many unique qualities. Some academics focus on the collaborative creative process that harnesses the non-monetary contributions of many people to a common goal (Shirky, 2010), while others emphasize that users are liberated when access to source code is granted because they have the ability to tinker with and modify the technology (Torvalds, 1999). OSS has been described by some as a successful economic model for the production of software (Perens, 2005). Others have claimed it is a threat to proprietary software businesses, and to the overall economy (Greene, 2001). OSS is often believed to be a more democratic and non-commercial model, yet many open source projects, like Linux, are used for commercial gain and are predominately developed by corporations to compete with software monopolies. For example, 75 per cent of the code in the Linux kernel is contributed by corporations who normally compete with each other, such as Red Hat, Intel, Novell, IBM and Oracle (Kroah-Hartman, Corbet & McPherson, 2009). With such conflicting opinions of OSS, it is not clear why a company would embrace it or reject it.

With Google's business booming, it seemed like an unusual choice for Google to develop two products as open source: the Web browser, Google Chrome; and the smartphone mobile operating system, Android. It made me question what I knew about OSS and forced me to reconsider my

suspicions of Google. At first glance, it may appear that Google has developed these OSS projects for very altruistic reasons: to make the Web faster (McCloud, 2008) and to bring smartphones and tablets to the poorest countries in the world (Arthur, 2011). But Google is a corporation with a mandate to make money for its shareholders, not to improve society. In this paper, I will explore why Google decided to make Chrome and Android open source. This research will add to the knowledge of the benefits of OSS and provide critical analysis of Google's business practices. The results will be valuable to people interested in developing OSS projects and to people who are interested in protecting open access and innovation on the Web.

Methodology

To discover why Google has embraced OSS for Chrome and Android, I will first analyze the literature on the origin and history of software and OSS in the context of the knowledge economy, exploring how OSS works while revealing many advantages and some common criticisms. I will highlight the lessons learned, by reviewing a case study of the browser wars, exploring theoretical reasons why Google would choose to make Chrome and Android open source. Then I will examine how late entrant Google, who has never sold software, has threatened the standard of technology giants Microsoft and Apple by using OSS in two different software markets, Web browser and smartphone operating systems. First, the browser war case study is extended to include Google Chrome's rapid success with OSS. Chrome's global usage share has grown sharply from 4.66% in November 2009 to 25.69% at the end of 2011, eating into the market share of both IE and Firefox, who finished 2011 at 40.63% and 25.23% respectively (Statcounter, 2011). Then, using the same framework, I will extend the analysis into the smartphone competition. For years, the RIM BlackBerry and Apple iPhone have been leaders in the North American smartphone market, with Nokia leading in Europe. While hardware features play an important role in the popularity and success of smartphones, the underlying operating

system often limits new entrants from competing. Developing complicated software is slow and expensive and can rarely keep up with the pace of the mobile market. Generally, each handset manufacturer develops its own proprietary OS – for example, RIM's BlackBerry OS or Apple iPhone's iOS. Smaller mobile manufacturers struggled to compete due to the complexity of developing a smartphone mobile OS, until Google launched Android as OSS and made it available to any manufacturer for free.

To discover reasons why Google chose to develop Chrome and Android as OSS, the two case studies build on a theoretical framework developed by Oshri et al. (2008). The framework was developed to examine the influence of both OSS and standards-setting during the browser wars of 2001-2007 among Netscape, Microsoft and Mozilla Firefox. The framework examines nine characteristics:

1. OSS origin
2. Development sponsorship
3. OSS program openness
4. OSS program's compatibility
5. Price of OSS program
6. Availability of support for OSS program
7. Quality of OSS program
8. Promotion Sponsorship
9. Strategic option

Data was gathered on each characteristic from published books, news archives, corporate Web sites, research reports, blogs and user forums. It was summarized in narrative form and was used to

analyze the role that OSS plays in the standards battle between the different software in each case study.

After discussing the limitations of this study and highlighting some questions for further study, the paper will conclude with an analysis of the reasons why Google chose to make Chrome and Android OSS.

Managing Information in the Knowledge Economy

OSS is about sharing. Many organizations struggle with the idea that sharing information can provide new and more powerful knowledge. This is particularly true for technology companies. But software is a digital commodity that should no longer be managed with analogue rules. Management scholar Peter Drucker, who coined the term "knowledge worker", wrote prolifically on the management issues and opportunities arising in the shift from an Industrial Economy to a Post-Industrial Economy (Drucker, 2010). He explained how corporations in the industrial economy profited from scarcity, but that in the post-industrial economy, corporations could no longer rely on restricting access to information with patents and proprietary systems. In the knowledge economy, there is an abundance of information and it is more difficult to control. Communications scholar, Dan Schiller (2003) explains that information wants to be free – it is a "common good" because it is cheap to reproduce and so easy to share. Software isn't consumed the way a loaf of bread is eaten; like knowledge, it is not depleted when used and "there is no cost to copy software an infinite number of times" (Weber, 2004, p. 73).

The music recording industry, like early technology companies, is struggling to succeed in the knowledge economy because of outdated management of a digital commodity. It tries to maintain an industrial model of distribution by limiting the sharing that naturally occurs with digital files in a networked world. Tapscott and Williams (2006) argue that the music industry could remain relevant

and profitable if it accepts that it no longer provides a product, but a service. They suggest a model where users pay a small monthly fee for unlimited streaming and that record labels and artists be compensated each time a song is streamed, which would eliminate the problem of illegal downloads. However this type of solution requires a major shift in management.

Google may have an advantage over other technology companies because it was born in the knowledge economy to manage the abundance of information. Unlike other media companies that tried to manufacture scarcity, Google learned early how to profit from abundance (Vaidhyanathan, 2011).

But in the early days of computing, resources were scarce. There were few computers available so demand for software was low. Early computers were large, expensive and rare. They came with simple programs to allow them to function and there was little need for additional programs. Pioneers of the commercial computing industry, Thomas J. Watson Senior and Junior were not programmers, but businessmen who made IBM wildly successful by locking in customers with proprietary solutions (Lunenfeld, 2011). Because of hardware scarcity, computer manufacturers could dictate how the machines would be used. With few mainframe computers available, time was rationed on the machines, limiting experimentation and innovation.

The demand for software increased with the introduction of Digital Equipment Corporation's (DEC) micro-computers, followed by IBM's AS400, which made computing affordable for many businesses and universities (Lunenfeld, 2011). And the demand for software has not decreased since. Moore's law says that computer processing power will double and the price will half every eighteen months (Lunenfeld, 2011). Unfortunately, no such law exists for software. Computers are faster, more powerful and less expensive, but the relatively slow development of software is limiting the development of the knowledge economy (Weber, 2004). Some believe that OSS can help accelerate development.

The invention of the Internet has facilitated sharing and further increased demand for software. The Internet is an end-to-end system, with intelligent ends but a "stupid" middle, unaware of what information it is carrying (Lemley & Lessig, 2001). Knowledge is a source of power and control in networks (Weber, 2004). But the Internet carries little control, pushing power out to the edges, distributing decision making to Internet users, making it open and accessible.

However, there is no guarantee that the Internet will remain open and accessible to all which may restrict sharing. Columbia law professor Tim Wu (2010) explains that other mass media like radio, telephone, television and film were all free and open in the beginning, but an industry developed around each invention that later transformed into a monopolistic empire. Wu cautions that the Internet could one day be owned and controlled by a monopoly.

In an historical analysis of the Internet, Rowland (2006) explains that it developed as a mass medium "of, by and for ordinary people" (p. 363) which avoided early corporatization, unlike radio and television. Early commercial interests had to respect the importance of the individual user, which had evolved out of the "hacker ethic" (Levy, 1985; Raymond, 1999b). Part of Google's success may be its understanding and respect of the hacker ethic. It focuses on user experience (Google, n.d.b), not on bombarding users with a home page cluttered by sponsors and commercial content. Google has been a leader in the Internet services industry, but will it survive the jump to the next wave of innovation: mobile computing?

Companies that dominate at one point in the history of media communications tend not to lead in the next phase. This can be explained somewhat by the "innovators dilemma": how organizations and individuals face an on-going struggle between the exploration of new products and the exploitation of existing products (Christensen, 1997; March, 1991). It is difficult for leaders to know when to

abandon a standard for a new invention, often leaving innovation to their competitors. Is it possible that Google is embracing OSS to maintain its lead for the jump into mobile computing and beyond?

The origin of Open Source Software

The open source movement found its roots at MIT's artificial intelligence lab, where students given a small taste of computer power were intoxicated by the potential. Unhappy with the limits set on access, they began working together around the clock, sharing code to maximize their efforts (Levy, 1985; Stallman, 1999). Feeling confined by the centralized authority over the mainframe computer, these self-proclaimed "hackers" felt that "all information should be free" (Levy, 1985, p. 40) in that everybody should have the liberty to use and modify it. They developed an ethic advocating hands-on computer use, freedom of information, merit over credentials and decentralization over bureaucracy (Levy, 1985; Raymond, 1999a).Their cooperative and open approach to programming allowed them to rapidly advance the uses of the computer to extend far beyond complex math calculations to creating games and even a robot that could catch a ball. The operating system, "the software on a computer that enables applications and the computer operator to access the devices on the computer to perform desired functions" (Proffitt, 2009para. 1) was open and they could inspect it at will. Because the system was open, they discovered new uses beyond any imagined by the computer's original inventors. But they were still limited by access to hardware.

With new hardware came new operating systems which were protected by patents and restricted to the user. In 1975, Harvard dropout Bill Gates and his friend Paul Allen founded Microsoft after writing interpreter software for a newly available microcomputer, the Altair 8800 (Levy, 1985). Software was suddenly a product and many MIT "hackers" took lucrative jobs in this new industry. Richard Stallman, a hacker who appreciated the community of sharing and ethos of helping your neighbours did not agree with the proprietary software rules limiting the right to copy. When his fellow

programmers set limits on the freedoms of software, Stallman remained true to his ethic and left the MIT lab to develop a free version of the UNIX operating system called GNU, or "Gnu's Not Unix" (Levy, 1985, p. 427) which opened the door for many free and open innovations.

Stallman founded the Free Software Movement in 1983, to give users full access to the software that they were running, so the program and developer do not have "unjust power" over the user (*What is free software?*2012, para. 4). However, the name *Free Software* is confusing because free has several synonyms. Free in this case is often incorrectly believed to refer to *no charge* rather than *liberty* or *freedom*. And to confuse matters further, Free Software is often distributed at no cost as well. The Free Software Foundation (FSF), the organization that manages Free Software, tries to reduce the confusion by suggesting that readers "think of 'free' as in 'free speech', not as in 'free beer'" (*What is free software?*2012, para. 4).

There are four freedoms that Stallman says are essential to free software development which in practice require open access to the source code:

- Freedom to run the code
- Freedom to study how the program works and to modify it to suit your needs
- Freedom to redistribute copies, either gratis or for a fee
- Freedom to change and improve the program and to redistribute modified versions of the program to the public so that others can benefit from the improvements (Stallman, 1999).

Stallman also created the General Public License (GPL) in order to ensure that all users could enjoy the same freedom. Otherwise, nothing would stop a programmer from taking a piece of free software in the public domain, making improvements and then closing it off in a proprietary form, keeping others from benefiting from the advances. Licenses "act as the practical manifestation of a

social structure that underlies the open source process" (Weber, 2004, p. 85). Stallman cleverly uses copyright to provide "copyleft", a "general method for making a program (or other work) free, and requiring all modified and extended versions of the program to be free as well" (Stallman, 2011, para. 11).

Despite Stallman's strong belief in the benefits of Free Software, the idea did not attract mainstream attention until Finnish graduate student, Linus Torvalds, wrote the kernel and released the source code of a new Unix-like operating system in 1991. The kernel is the core of the operating system that bridges the applications (like Word) with the data processing done at the hardware level by the central processing unit (CPU), memory and devices (Torvalds, 1999). He called it Linux. As a computer science student, Torvalds was using the MINIX operating system, a simplified version of UNIX created by University professor Andrew Tanenbaum for educational purposes. But Torvalds didn't like the restriction that MINIX could only be used in non-commercial applications. Stallman's GNU project was working on an open kernel but it wasn't available yet, so Torvalds wrote his own kernel from scratch, as a hobby (Moody, 2001). He was shocked by the response to posting his kernel on the comp.os.minix newsgroup. Because the infrastructure of the Internet already existed, it was easy to reach like-minded programmers around the world who were hungry for a free and open alternative operating system (Weber, 2004). Torvalds (1999) states that "the power of Linux is as much about the community of cooperation behind it as the code itself" (p. 108). Linux is developed collaboratively with contributions from a wide variety of people. The risks and rewards are spread over a larger ecosystem that stimulates innovation (Weber, 2004). The Linux foundation reports that "over 1,000 developers, from at least 100 different companies, contribute to every kernel release" (Proffitt, 2009). Linux is popular with programmers and administrators who manage servers because they can modify and make changes to the code for their specific needs, but most home personal computer users don't

have the need or skill to do so. Less technically proficient people are content to use proprietary operating systems like Microsoft Windows or Apple's OS X on their home computers. But Linux contributes to our digital lives almost daily without us even knowing. It powers a range of commercial and non-commercial systems like research supercomputers, the New York Stock Exchange, or the One Child Laptop, and smaller devices like GPS navigation systems, digital video recorder TiVo, and the Sony Bravia flat screen television (Proffitt, 2009). The continued successful adaptation of Linux around the world has proven that open source software has a wide and enduring appeal.

Bruce Perens, the project leader of a Linux distribution called Debian, thought that Free Software needed a different name so it could be more effectively marketed to a wider audience. To make it more appealing to business people, he wanted to emphasize the collaborative benefits over the liberal freedom ideals stressed by Stallman (Perens, 1999). He called on Eric Raymond (1999) who had successfully used the cathedral and the bazaar as a metaphor to describe the organizing differences between proprietary software and OSS development. Raymond had written how a cathedral is designed and then built with a master plan, with a top down hierarchy, as opposed to a bazaar that develops organically according to the needs of the community, attracting more people but without a master plan at the outset. Raymond understood the open source community and was able to articulate it to outsiders, allowing the movement to gain acceptance in the business community. Raymond and Perens agreed that dropping "free" from the name would reduce the need to clarify that Free Software is "free as in speech, not free as in beer" (Stallman, 1999).

To choose a new name, Perens and Raymond gathered leaders from many free and open source projects including John Hall and Larry Augustin from Linux International, Michael Tiemann from Red Hat and Chris Peterson of the Foresight Institute. They decided on the name Open Source on February 3, 1998. Perens (1999) then wrote the Open Source Definition based on the Debian Definition.

Richard Stallman and the FSF were interested in the new name but decided not to adopt it. OSS is based on the ideal that property should be configured around the "right and responsibility to distribute, not to exclude" (Weber, 2004, p. 86). The Free Software movement values the ethics of freedom and believes that access to the source code is a necessity of that freedom, whereas the Open Source movement sees access to the source code as a practical issue. The two groups are very similar but have "a different approach, a different philosophy, different values, and even a different criterion for which licenses are acceptable" (Stallman, 2002). Each group firmly believes that their name and approach is superior, but according to Stallman (2002), the two groups work together frequently despite these differences and consider proprietary software to be the enemy, not each other.

Both Free Software and OSS began in the United States but have global communities supporting them. Some groups attempt to recognize both points of view by using the combined terms Free/Open Source Software (FOSS) or Free Libre Open Source Software (FLOSS) (Weber, 2004), but neither the Free Software Foundation nor the Open Source Initiative accept or use these names. Since this paper is focused on the commercial adoption of Open Source Software, the term OSS will be used, as this name is more frequently used by the organizations expanding the use of open software.

How does Open Source Software work?

OSS recognizes that knowledge is not depleted when it is used; rather, it benefits from the growth of knowledge that results from sharing. OSS "harnesses the power of distributed peer review and transparency of process" with the promise of "better quality, higher reliability, more flexibility, lower cost, and an end to predatory vendor lock-in" (Open Source Initiative, n.d.a). OSS distributes decision making, like the Internet. Because the source code is available with OSS, it does not discriminate and there are low barriers to entry. Without a central person in control, nobody is setting

the agenda, so people can participate where and when they want, leading to what Weber calls, distributed innovation (Weber, 2004).

There are a number of licenses available for OSS projects (see Table 1) depending on the needs of the authors. Developers are advised to choose an existing license rather than create a new definition in order to increase innovation, because "fragments of one program cannot be used in another program with an incompatible license" (Perens, 1999, p. 184).

Table 1

Comparison of licensing practices in OSS (Perens, 1999, p. 185)

License	Can be mixed with non-free software	Modifications can be taken private and not returned to you	Can be re-licensed by anyone	Contains special privileges for the original copyright holder over your modifications
GNU General Public License (GPL)				
GNU Library General Public License (LGPL)	X			
X, Berkeley System Distribution, and Apache Licenses (BSD)	X	X		
Netscape Public License (NPL)	X	X		X
Mozilla Public License (MPL)	X	X		
Public Domain	X	X	X	

Since many contributors to OSS projects are volunteers, some would call their contribution a hobby. But this is "productive leisure" that allows the individual to participate in work-like behaviour

without being forced to do so (Gelber, 1999). Eric Raymond (1999) also explained open source as a gift economy, "a phenomenon of computer programmers having the leisure to do creative work not connected to their employment". While this was true in the early days of OSS, many contributors are now paid a salary for their efforts, often by sponsoring organizations that have a stake in the joint development of a product to compete with a monopoly. However, individual contributors to OSS projects are free to choose what parts of the project that they work on and when.

Bruce Perens (2005) argues that appeal of OSS goes far beyond the way it is organized, and presents a compelling economic paradigm that proves that OSS is both sustainable and positive for the overall economy. He found that only 10% of the software in any business is "differentiating", meaning that it differentiates one business from another. He uses the example of Amazon's book recommending feature which has proven to be the reason Amazon sells more books online than all other book retailers. Perens explains that it would be foolish to share the functionality of this differentiating software; however non-differentiating software, like the checkout software, could be shared without hurting the competitiveness of the business. Companies like HP and IBM contribute to and support Linux because they both need an operating system that they can customize, and they compete on other factors. These businesses have shown how open source collaborations produce software more efficiently than other economic paradigms for producing software that does not differentiate its user's business. Google's search and advertising software differentiates its business from others, therefore according to Perens' research, it would not be advisable for Google to make that software open source.

DiBona, Ockman & Stone (1999) explain that innovation is accelerated when information is shared. The scientific method and peer review is responsible for great advances in the natural sciences. A scientist's research is only accepted if the results are repeatable. For computer science to benefit

from the same acceleration of innovation, the source code must be accessible, so you can "provide them with the means to compile and run the program" (DiBona et al., 1999).

Open development spurs innovation. The Internet was initially developed as a network to allow individual computers to connect with each other so they could share information. Concurrently, corporations like AOL and Compuserve developed their own closed proprietary networks that delivered content to subscribers and only allowed limited communication between network members. They created "walled gardens" that controlled users' movement and bundled content, limiting free flow of information and ideas. The restrictions also eliminated the ability for users to tinker with the system, therefore cutting off any potential innovation and spin-off inventions. This closed architecture stalled the development of online services, eventually making the walled gardens less attractive to users (Rowland, 2006; Zittrain, 2009). The Internet, on the other hand, allowed anyone with basic programming skills to develop and distribute Web applications, with the best services gaining in popularity while the poorer ones fell into obscurity. The rapid creation and distribution of new online content had a generative effect, spurring innovation and creativity, whereas walled gardens stalled development, creating a static user experience (Zittrain, 2009). OSS projects like Linux demonstrate that many citizens have both the skills and the will to contribute freely to an open project. Zittrain (2009) warns that when citizens don't have the right to contribute, great ideas will never be realized, and society will lose out on the generative effects of that creativity.

Beyond the license, the essential difference between proprietary software and OSS is the "coordination, selection, and assignment of the work" (Mockus, Fielding, & Herbsleb, 2002, p. 34). It facilitates a "distinctly different culture that leverages the law of large numbers and exploits the strength of weak ties" (Weber, 2004, p. 28) and allows huge armies of people to contribute to a project without clogging up the process (Shirky, 2010). A study found that developers of proprietary software

were discouraged from collaborating because they felt they were working in silos, and that formal lines of communication made it more difficult and time consuming to communicate across teams (Herbsleb & Grinter, 1999).

Non-programmers have become interested in OSS because of the process, not the product. Economist Steve Weber (2004) describes OSS as a new "production process", comparing it to the Ford assembly line or the Toyota lean production process (p. 56). All three processes are independent of the product allowing the process to be adapted to other types of production. OSS production was developed as a way to make software but has also been adopted by other processes, like building new models for government (Booth, 2010; Weber, 2004) and as a model for a more democratic media system where individuals will have the opportunity to see themselves as citizens rather than consumers (Milberry & Anderson, 2009).

While OSS development is supported by many corporations such as IBM, Xerox and Oracle, it has its foes. OSS is criticized for a lack of responsibility for development; unclear process; lack of quality or support; incompleteness and poor integration; low user-friendliness; absence of complementary products; and lack of compatibility (Mendys-Kamphorst, 2002). Others warn that OSS requires profound patience because development may be slow and unwieldy to manage (Jaffe, 2010).

Proprietary software companies do not generally support OSS, although this appears to be changing. In 2001, Microsoft CEO Steve Balmer stated that "Linux is a cancer" (Greene, 2001). But even Bill Gates could not ignore the power and momentum of OSS. In 2006, he named Sam Ramji to lead the Microsoft open source strategy and hired Linux guru Bill Hilf away from IBM. With the results from this internal team, Gates acknowledged the competitive advantage of OSS in 2008 and declared that Microsoft must move in that direction (Metz, 2012). In 2011, Microsoft announced it

would port two Linux technologies for managing big data, Node.js and Hadoop, to Windows Azure and then contribute the code back to the OSS community (Metz, 2012).

While there is disagreement over what OSS is, or how it should be governed, projects like Linux continue to demonstrate the effectiveness of OSS. There are many positive benefits of OSS to both the individual user and society in general. The increased speed and efficiency of computer hardware has accelerated the demand for software to the point where innovation is lagging while waiting for software solutions. When individuals and organizations share code and work together to create an integrated solution for non-differentiating software, as in the case of the Linux kernel or Hadoop, developers can focus energy on creating software to solve real world problems that urgently need attention rather than compete on creating a different platform.

But OSS is not just about a more inclusive and efficient way to make software. It also makes good business sense. Many organizations want to benefit from the generative effects of the Internet, and Google is no exception. As a business, Google wants more people using the Web and making more searches so it can sell more ads. This is similar to the way that early broadcasters wanted a radio in every home so their sponsor ads could reach more ears (Wu, 2010). Each browser is like a different radio station, giving preference to the content and ads that it chooses. Of course Web users can make alternate choices, but most will stay with the default setting, which usually favours the specific browser. Since Google's primary business is advertising, browser software and mobile OS software does not differentiate them from other businesses. Instead, this software helps to bring more users to Google's lucrative products. Therefore on a theoretical level, OSS seems like a good choice for Google.

Google was an active participant in browser wars, contributing to the OSS project that threatened Microsoft's standard. What lessons did Google learn that made it choose to build its own OSS browser and then an OSS mobile operating system?

OSS in the browser wars

The browser wars have been well documented in academic literature as evidence that OSS can compete with proprietary software (Gruener, 2008, Weber, 2004). They illustrate how situations with one dominant standard stifle innovation and creativity. It is a cautionary tale where OSS doesn't always win. It is the story of a dominant product that failed to respond to user needs, and the underdog, an unlikely alliance of programmers from different companies with competing interests, who collaborated to create a better product with OSS. It is an accessible case study of OSS because browsers are used by anybody who has ever explored the Web, compared to Linux, which is far more abstract for average computer users. The browser wars are important to anybody considering participating in or developing an open source project because the episode shows both the shortcomings and benefits of OSS over a 16 year history. The case study is also useful because it provides a theoretical framework to assist in analyzing the characteristics of OSS in other software markets and is extended to the two case studies in this paper.

Browser war One (1995-1999)

Early browsers were text-only with limited appeal to non-technical users. The first graphical browser, Mosaic, developed at the University of Illinois, was released in November 1993, helping to expand and popularize the Internet (Oshri et al., 2008). Released in December 1994 with improved reliability and usability, Netscape Navigator took more than 60% of the market in less than six months and was worth $7 billion one year later (Cusumano & Yoffie, 1998). It wasn't until 1995 that Microsoft CEO Bill Gates recognized the importance of the Internet and began pushing browser

development at Microsoft (Gates, 1995). To avoid competition, Gates suggested that Netscape build non-Windows browsers exclusively, but when it declined, he declared war (Oshri, de Vries, & de Vries, 2010, p. 838). Microsoft invested over $100 million per year from 1995 to 1997 developing Internet Explorer (IE), but it did not threaten Netscape's lead until version 4.0, released in October 1997, finally matching the features of Netscape (Yoffie & Kwak, 2001). IE 4.0 was faster and supported CSS specified by the W3C (Reid, 1997). Microsoft further ensured its dominance by building relationships with Web developers so they would optimize their designs for IE and by creating FrontPage, a WYSIWYG (What You See Is What You Get) HTML editor optimized for IE. Knowing that Netscape was dependent on revenue from server software sales, Microsoft stopped charging a fee for its Web site server software, Internet Information Server. It also made deals with Internet Service Providers (ISPs) such as AOL to distribute IE as their default browser, and bundling IE as the exclusive browser along with the Windows operating system on new PCs (Oshri et al., 2008).

In January 1998, to compete with Microsoft, Netscape announced it would release its source code to "ignite the creative energies of the entire Net community and fuel unprecedented levels of innovation in the browser market" (*Netscape announces plans.* 1998). With the assistance of Eric Raymond, the man who helped rename open source software, Mozilla.org was founded as a clearing house for Netscape code. The code was released on March 31, 1998 (Hamerly, Paquin, & Walton, 1999) but development failed to take off. In October 1998, IE was the most popular browser. By 2002, IE controlled 90% of the browser market (Corts & Freier, 2003).

Without any competition, Microsoft's market share grew to 93% by the end of 2003 (see figure 1) (Krishnamurthy, 2009). After releasing IE6 in August 2001, Microsoft completely abandoned browser innovation, planning instead to combine the browser with their proprietary operating system (Hansen, 2003). Over time, the browser features did not keep up with user expectations.

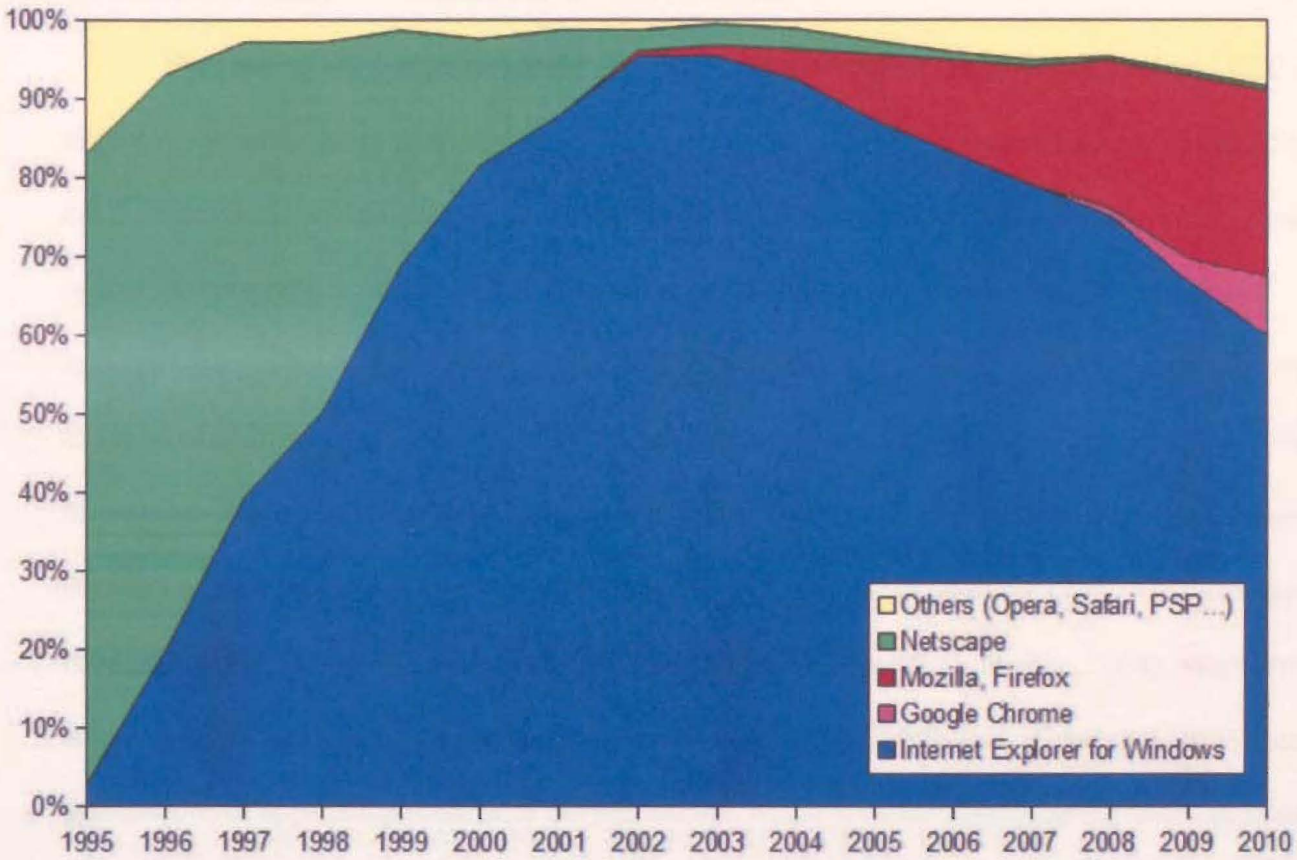

Figure 1. Browser Market Share for 15 years. This figure shows how the market share for Internet Explorer (blue) peaked in 2002, until threatened by Mozilla Firefox (red) which began launching beta versions as early as 2001. Retrieved from http://en.wikipedia.org/wiki/File:Browser_Wars.svg on 12/1/11.

Microsoft was a profitable leader in the software industry for decades, and because of their disproportionate market share, was able to ignore open standards, as, for example, when they imposed non-W3C compliant tags in HTML with their Internet browser IE (Cerri & Fuggetta, 2007). Because of the market dominance of Internet Explorer 6 (IE6), Web designers often created Web sites that were only compatible with the IE6 browser using some non-standard tags, which "broke" or rendered differently in other standards compliant browsers, such as Firefox, Opera or IE7. After five years as the dominant browser and without any serious competition, IE had no incentive to innovate or to comply

with open standards. Furthermore, there was a disincentive because even a small change to their browser could disrupt thousands of customers (Keith, 2008).

The Internet uses open standards governed by the World Wide Web Consortium (W3C), which allows the work of many unrelated people to function together in a coherent and useful way. Standards are the rules or definitions that describe the way something functions. Open standards are managed openly, are publicly available and allow for unrelated groups to develop interchangeable and interoperable products (Cerri & Fuggetta, 2007). Apple has traditionally maintained a closed standard, always maintaining tight control over its operating system and hardware, locking out others from innovating on top of their products and limiting the size of its market. In the 1980s, IBM opened the standard of their personal computer, allowing others to create interoperable products which appealed to consumers, making the PC the dominant computer format (West & Gallagher, 2004). More recently, Apple opened its application programming interface (API) to developers, allowing them to create applications or apps compatible with the Macintosh. Apple now benefits from the innovation of third parties the way IBM did in the 1980s.

Browser war Two, Part 1 (2004-2008)

Netscape's open source project struggled for a few years. The code base was outdated and difficult to work with, so the development community began building on a new codebase, Gecko, which was released with an OSS license. Gecko is cross-platform compatible with Windows, Linux and Mac OS X plus it supports open standards: CSS, DOM, XML, and JavaScript.

Mozilla was down but not out. Its goal was to diversify the Web to ensure that the Web wasn't controlled by a handful of companies (*History of the Mozilla project.*2011). It found allies at IBM, HP and Sun, who needed to ensure that they would have a browser on their Internet-connected workstations. Each had valuable OSS experience as they had been contributing to Linux for years.

They provided engineers to work on the Mozilla project to guarantee compatibility with their systems (*History of the Mozilla project.*2011; West & Gallagher, 2004).

As OSS, Mozilla development is governed by a practice of distributed decision making and distributed peer review described as a "hierarchical meritocracy" (Booth, 2010). The code is broken into modules, each with an owner who designates peers to help determine the utility of patches and makes final decisions about modifications to the module. Committers are developers who have submitted a patch that is accepted into the code. They must submit a formal application to become a committer and nominate peers to "vouch" for the patch. This system ensures speed and reliability to the process. Firefox has three types of contributors: employees of Mozilla; employees of institutions that contribute to the Mozilla project (i.e. Google, IBM, Sun, Red Hat, Hewlett Packard, Oracle, Novell); and unpaid volunteers (Hecker, 1999). Mozilla development is attractive because anyone can use Mozilla code to create a commercial product; the Mozilla Public License (MPL) does not require developers to turn their Mozilla-based applications back to the open source project (Baker, 2004). This differs from the GPL license which doesn't allow commercial derivatives or combining OSS with non-OSS (Perens, 1999).

Mozilla Firefox 1.0 launched on November 9, 2004 to rave reviews. It was promoted by community members with the Spread Firefox campaign as well as sponsors like Google and IBM who included Firefox in their software packs (Krishnamurthy, 2009). Firefox claimed between 5-7% market share in the first month (Gruener, 2008). Early adopters of Firefox were primarily non-corporate and technologically advanced (Perez, 2005). Many users switched, especially in Europe, because it was perceived to be more secure (Broersma, 2005b; Morrison, 2004), had more features, was more standards-compliant and therefore less vendor dependent and more innovative, and provided a better user experience (Broersma, 2005a). IBM promoted Firefox as their preferred browser, and companies

like Boeing and Fidelity Investments provided feedback to Mozilla on how to make Firefox enterprise-ready. However many IT managers would not support Firefox, often because of their reliance on Web applications that only functioned in IE (Sliwa, 2004). This is an example of how an inferior product can remain the standard when switching costs are too high. Users become "locked-in," whereby "users are not willing to abandon the standard they have adopted because the cost of switching to a new standard is too significant" (Oshri et al., 2008, p. 27). However, by the end of 2008, Firefox claimed over 20% of the browser market, cutting deeply into IE's share, and showing that OSS could be a worthy competitor to proprietary software (Gruener, 2008).

While competition was building, Microsoft IE still held the dominant share of the market and continued to ignore compliance with open standards. In 2005, Microsoft announced that IE6 SP1 would be its last stand-alone browser and that the browser would become a part of the new OS. It planned to use a new proprietary XML language called XAML, hoping to make stand-alone browsers obsolete, by incorporating browsing into the desktop (McHugh, 2005). But the minor browsers joined forces to fight back. Mozilla worked with Opera to develop new open standards with more capabilities that would be backwards compatible with existing technologies. They formed the Web Hypertext Application Technology working Group (WHATWG), with Apple joining later.

This strategy paid off, attracting more users away from IE and protecting open standards on the Web. A notable difference between browser wars was the transition from "supplier push" to "user pull" (Oshri et al., 2008, p. 134). Microsoft set a standard using its operating system to push people to use IE, whereas Firefox built a standards compliant browser that was safer and more innovative, pulling new users to the product. However, there are limits to how many users can be pulled because a large number of computer users don't know the difference between a browser and an operating system and they don't really seem to care much about quality, security or features, often relying on the browser that came

installed with their system (Oshri et al., 2008, p. 42). Furthermore, many people find protecting their privacy to be confusing and burdensome, so don't bother with it (Stalder & Mayer, 2009, p. 110).

Assessing the impact of OSS: A Theoretical Framework

In order to assess the role that OSS played in the rise of Firefox, Oshri et al. (2008) conducted a thorough evaluation of the first two browser wars up to 2008. The application of the theoretical framework introduced earlier revealed four elements of impact that OSS had on changing standards-setting activities (Oshri et al., 2008, p. 136).

1. The open license makes it attractive for firms to participate in the standard's development and promotion.
2. Having other companies involved in creating the browser was key to the success of the standard.
3. Because each sponsoring company is involved for different reasons (Mozilla to create a product, Netscape to create a commercial derivative, IBM to combine it with other software packages, Google to avoid standard lock-in), some will become competitors after the development phase.
4. Superior quality of the standard was further enhanced by OSS characteristics.

The study concludes with a warning that because OSS products don't lock in their installed user base, these products can more easily be "forced out of the market by a proprietary rival product of superior quality with network effects in its favour" (Oshri et al., 2010, p. 853).

I would propose that Google made both Chrome and Android OSS because doing so is the fastest and least expensive method to compete in non-differentiating software markets (Perens, 2005).

However, the theoretical framework will be applied in the two case studies with the objective of discovering further reasons why Google has embraced OSS for some of its new products.

Case Study 1: Google Chrome in the browser war (2008-2011)

In 2008, IE still had the largest share of the market, but Firefox had a large enough share to keep IE from dictating the future of the Internet. This was a major victory for OSS and supporters of the open Web. However, the battle for territory did not end with this study. When Google launched Chrome on September 1, 2008, a new competition began. As Oshri et al. (2010) predicted in point three above, because Google was involved in the development of Firefox for a different reason than Mozilla, they could become competitors in the future.

For years, Google claimed that it didn't need to build a Web browser and instead invested heavily in the development of Firefox and Safari. Mozilla was also supported with revenues from search providers Google, Yahoo, AskJeeves, Amazon and eBay for placing them in the default search toolbar since version 1.5 of Firefox (Softpedia, 2005). However Mozilla's largest supporter is Google, who has reportedly provided 85% or more of Mozilla's annual revenue for promoting Google as the default search engine on Firefox (Kincaid, 2008; Anthony, 2011). However, the company changed its mind claiming that other browsers, especially IE, were not keeping pace with the complex applications developers were building on top of browsers (Waters, 2008).

Google may have chosen to make Chrome OSS for the reasons it claims – because it is a champion of open systems because they "lead to more innovation, value, and freedom of choice for consumers, and a vibrant, profitable, and competitive ecosystem for businesses" (Rosenberg, 2009). Rosenberg (2009) openly reveals that his motives are profit-driven, and that open systems will create a better Internet with more users and much healthier business sector, which will lead to a bigger bottom line for Google and for others who are able to innovate in an open environment.

Google is motivated to keep the Internet open to ensure that it won't be excluded from selling advertisements on competitor's browsers, like Internet Explorer. In 2008, Google's then-CEO Eric Schmidt stated that Chrome was designed to "stop Microsoft from Balkanizing the Internet in ways that favor its own services" (Waters, 2008, para. 1). Schmidt also points to the "500,000 pages of court testimony" of Microsoft favouring its own services (Waters, 2008, para. 4).

Google has invested heavily in creating its own browser. But why did it chose to make an OSS browser, where the code can be examined by competitors and used to make derivatives of it, potentially squeezing Google out of the browser market? What are the characteristics of OSS in this case that would make it appealing to Google?

Analysis: OSS characteristics of Chrome

Chrome is based on Chromium, an open source browser built by Google. Chrome is continually referred to as OSS, but it is not technically open since only the Chromium source code can be downloaded and modified (Dein, 2009). Google states that the only differences between Chrome and Chromium are Google branding, some user interface controls and packaging of the proprietary Flash player and PDF reader, which however would appear to violate the OSS license (McAllister, 2008). While I am suspicious of Google's motives for not releasing the source code of Chrome, proving that it is not OSS is beyond the scope of this research paper. Like other researchers and academics, I will assume that the source code for Chrome is the same as Chromium, and is therefore also open source.

Via the Chromium source code, programmers have the ability to look at the code, modify it, and re-package it as their own. To assess the impact of OSS in standards-setting during the browser wars from 2008-2011, Chrome is analyzed qualitatively according to nine categories identified by Oshri et al. (2008). The framework recognizes that some of these categories, such as OSS program openness, do

not have a binary response. The answer lies on a continuum between fully open and fully closed or proprietary.

OSS origin

Chrome and Chromium are based on the WebKit layout engine developed by Apple for its first browser, Safari, in 2003. WebKit is a fork (a branch from the main development to work in another direction) of another layout engine, KDE (Langley, 2008). WebKit is based on Apple's WebCore and JavaScriptCore which are licensed as open source under GNU Lesser General Public License (GLPL). The root of WebKit is partially proprietary because the code was developed by Apple in a closed environment and only shared with the KDE community a year after developing it in isolation. The source code of WebKit was opened in 2005 and is available under the BSD license which allows portions to be incorporated into both OSS and proprietary programs (Molkentin, 2005).

Development sponsorship

Most successful OSS projects are driven by a charismatic leader, such as Linus Torvalds for Linux, or Guido van Rossum for Python (who is referred to as the Benevolent Dictator for Life) (van Rossum, 2008). Instead, Chrome is led by a corporation that makes 97% of its revenue by selling advertising on the Internet (Dein, 2009, p. 14).

The development of Chrome is fully sponsored and controlled by Google via Chromium. The majority of Google's Chrome developers were Firefox contributors: Ben Goodger was the Firefox 1.0 project lead, Ben Fisher specialized in Firefox network libraries, Brian Ryner added mousewheel support to Firefox, Pam Green added OpenSearch and full-text search in the Places/Awesome bar, Ian Fette worked on anti-phishing, etc. (Kennedy, 2003). Chrome development is a one-sided push by Google to the community; it openly encourages the use of the Chromium code without fee, without asking permission, and without the need to share patches and report bugs (McCloud, 2008b, p. 37). A

few projects have already begun building on the code, including RockMelt, a new browser built on Chromium that enhances browsing by bringing online social connections into the experience (Baig, Lieberman, & Yu, 2010).

Google Chrome allows people to join discussion groups, file bug reports and submit patches for known bugs but it makes little effort to cultivate that community (Google, 2011). Project updates are coordinated via Google Code, but "only the issue owner, someone at @chromium.org or @google.com can check the box" to commit the change (Chromium, n.d., para. 2.1.1). Source code for Chromium is updated daily, whereas Chrome is released in stable batches that are automatically updated for the user.

OSS program openness

The source code of Chromium is released under BSD license which allows for closed versions to be created from it. While Chrome source code is not available, most consider it to be OSS because of its similarities to Chromium (McAllister, 2008). I would characterize it as OSS with strong proprietary undertones.

OSS program's compatibility

Chrome is fully compatible with all Web sites that are compliant with W3C-approved tags in XHTML, CSS, DOM and SVG. It may not be able to fully display sites that were specifically designed for IE6. As stated earlier, IE6 violated numerous W3C standards, but Chrome can partially display these sites.

Price of OSS program

There is no cost to download, install and use the Chrome browser. No browsers, not even proprietary browsers, currently have a fee to use them.

Availability of support for OSS program

Support is available online via articles and users can submit questions on forums (*Google Chrome help.* 2011). However, those questions are usually answered by peers, and rarely Google staff, forcing the user to read many responses before choosing the answer they believe to be most correct.

Quality of OSS program

Google's published aim is to "make the Web better" by improving the speed, stability and security on Web browsers (Google, 2011, para. 1). Starting from scratch the way Mozilla did in 2004, the Chrome team said they were able to build a better browser that responds to today's online demands like gaming and watching videos.

Speed has been improved by building a new JavaScript engine, V8, which "processes JavaScript 56 times faster than the most used version of Internet Explorer" (Minto, 2009). A test by Gomez real-user monitoring (see Figure 2) found Chrome 12 to be faster than competitors Firefox 5, Safari 5, and Internet Explorer 9, with a load time of only 3.433 seconds (Compuware Corporation, 2011). A similar test by PC World also found Chrome to be marginally faster than the competition (Mediati, 2009).

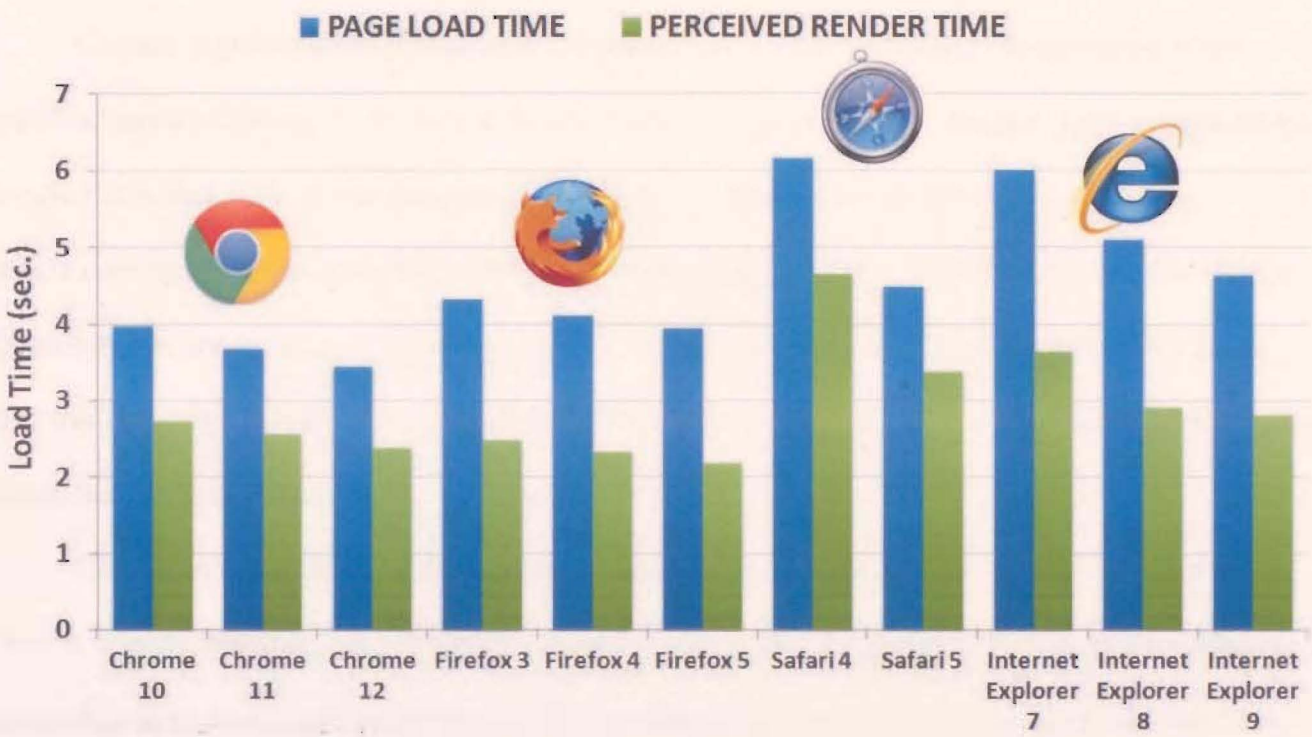

Figure 2: Performance Differences Across Browsers. This figure illustrates that Chrome 12 has the fastest load time of the top four most popular Web browers as of July 2011. Retrieved from http://www.compuware.com/application-performance-management/its-a-mobile-multi-browser-world.html on January 15, 2012.

Chrome engineers have been praised by computer scientists for building a more stable and secure browser by using "sandboxing to limit the amount of damage which can be caused at any given level, the automation of browser updates, and various technical strategies for protecting against malware"(Reis, Barth, & Pizano, 2009). However, the help forums for Chrome show a mixture of happy and frustrated users, many complaining of crashes while others praise reliability (*Google Chrome help.*2011).

In a small sample of comments made in user forums frequented by early adopters, some have claimed to abandon Firefox in favour of Chrome because of superior quality and speed. Yet a slightly smaller number expressed a continued belief that Firefox is superior.

Promotion Sponsorship

Chrome is promoted by Google, the company that owns the product. It suggests that users download and try Chrome on its popular Web tools like YouTube, Gmail, Google Apps, Google Maps, Google Earth, and more. It has direct access to over two thirds of the world's Web searches at Google.com and promotes switching to Chrome on this page as well (Cain Miller, 2011). The Google philosophy has always been to "focus on the user and all else will follow" (Dein, 2009 p. 20) but in 2011 that mantra changed when it began promoting Chrome in 90 second television commercials in the United States (Cain Miller, 2011).

Chrome has recently been bundled with other software. For example, Adobe was offering Chrome to users downloading Adobe Flash Player. This bundling attracted negative attention because it was packaged as an opt-out meaning that users would have to deselect a check box, rather than checking it to opt-in. This resulted in many inadvertent downloads and some bad will towards both Google and Adobe (Gertner, 2011).

Google made a special effort to win over the OSS and "techie" communities, those who were early adopters of Firefox. It hired famed comic book artist Scott McCloud, a hero to "tech nerds", to explain all the gritty details about Chrome in a language that techies can appreciate (see Figure 3) (McCloud, 2008a p. 38). Illustrations of the development team (many of whom contributed to Firefox) portray the features that make Chrome a superior browser and encourage others to use the code to improve Web innovation. It was created as a printed comic book to be mailed to journalists and bloggers for the launch of Chrome. When it was accidently sent two days early, the comic was the first thing that the world saw of Chrome (Gustines, 2008). Many recipients scanned the comic and posted it online to share with others, building hype and viral buzz for the launch. There is speculation that the leak was intentional, but Google maintains that it was an accident (McCloud, 2008b).

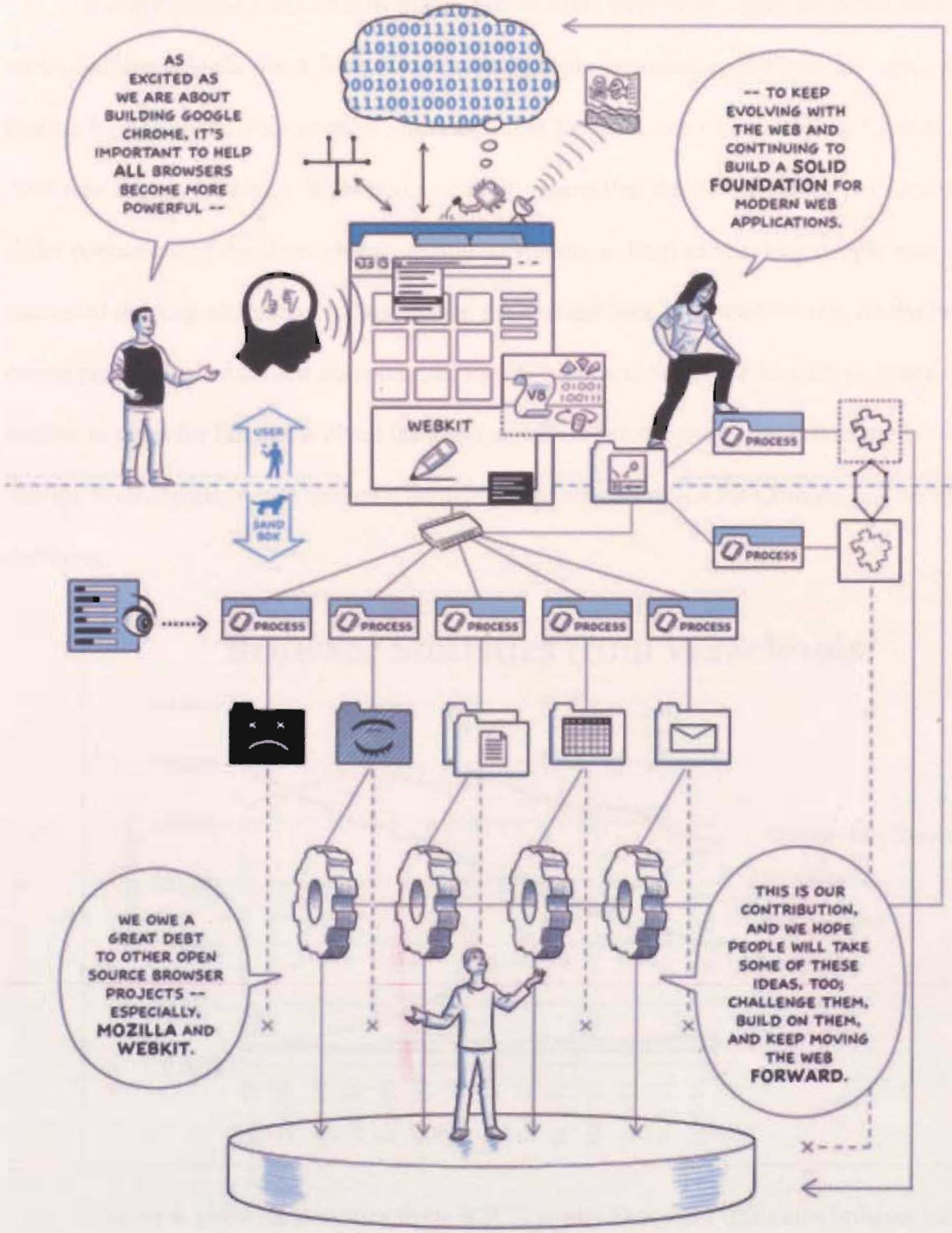

Figure 3. The final panel in Scott McCloud's printed comic sent to journalists and bloggers for the launch of Chrome. It speaks to the OSS and tech communities in a language that they appreciate and facilitates understanding for less technical people as well. Retrieved from http://www.google.com/googlebooks/chrome/small_38.html.

It is difficult to measure how many Firefox users have been pulled away to Chrome. The usage statistics from W3Schools, a Web site attracting people interested in Web technologies, shows that Firefox has lost about 10% of users whereas IE has lost 30% since the launch of Chrome in September 2008 (see Figure 4, below). W3Schools carefully warns that these statistics do not accurately reflect the wider population of the Web, characterizing its visitors as English speaking people who are more interested in using alternative browsers than the average user, who tends to rely on the browser that comes preinstalled with their computer, IE for PC users and Safari for Mac users. Since the relative decline in users for Firefox is about the same as with other statistics, like Statcounter, it would confirm that the Web-literate crowd has not completely abandoned Firefox for Chrome, but the numbers are declining.

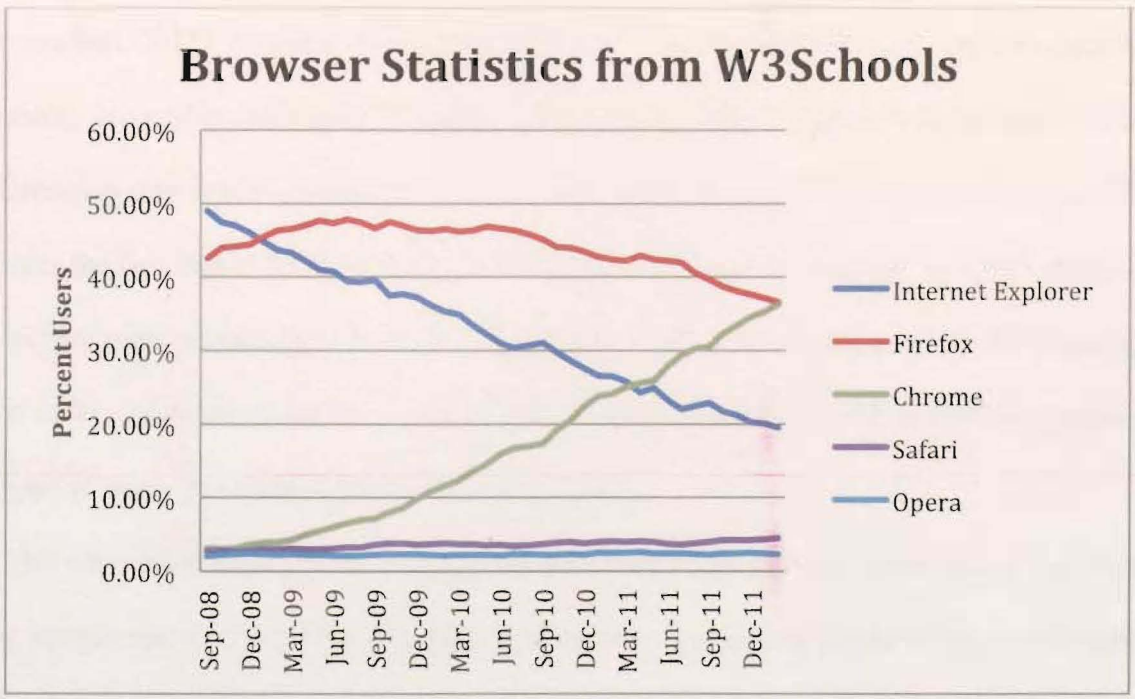

Figure 4. Browser Statistics from W3CSchools. This chart illustrates browser traffic to a Web site that attracts English speaking, tech savvy, Web users. It shows that since the launch of Chrome, Firefox has lost about 10% of users whereas IE has lost 30% of visitors to this particular site.

Strategic option

For hundreds of years, superiority of product and competitive price were the two ways to compete in business. Microsoft is not the best in either of these categories yet it still has the majority of the browser market. The Delta Model takes the network economy into the scenario and identifies three options for competition: best product, total customer solutions, and system lock-in (Hax & Wilde, 1999 p. 12). Chrome has very few features that differ from Firefox and IE (Oda, 2008), but it is competing as best product by showcasing speed, security and reliability. It is also competing on total customer solutions as the Chrome browser compliments the wide range of online tools that Google already offers, giving users a seamless experience across the Web (Ahmed, 2011 para. 22).

Discussion

Google, one of the most powerful and successful technology companies in the world (Vaidhyanathan, 2011), claims a very altruistic mission "to organize the world's information and make it universally accessible and useful" (Google, n.d.a, para. 1). But Google is less interested in content and information than it is in tracking a user's surfing habits (Prada, 2009; Stalder & Mayer, 2009). It never hides the fact that its primary business is search and online advertising. It openly states that its goal is to "get more people spending more time on the Web, so by opening up our APIs and getting others to make our products better, we get people to spend longer on the Web and make more searches on Google" (Chewy Tewhella quoted in Furness, 2009).

But why did Google choose to make Chrome OSS? The strategy has been very successful in building market share for Chrome, attacking both its top competitors, IE and Firefox. The analysis reveals that choosing OSS has improved its competition for a number of reasons.

1. A free codebase that was modified to meet its needs rather than starting from scratch.
2. A supply of experienced in-house talent who had contributed heavily to OSS projects including Firefox.

3. Generative effect: Chromium source code is available for other projects like Rockmelt.

4. The OSS Community followed: Many of the OSS developers contributing to Firefox left to work on Chrome. The grassroots community that made Firefox such a success is now impressed with Chrome (Asay, 2010). It matches Firefox's "open-source bona fides, and raises the bar with an expansive view of what the browser can and should do" (Asay, 2010).

Mozilla has been criticized for becoming too conservative, and now those critics have an open alternative. However, statistics from W3Schools show that Firefox may not have lost as many tech savvy supporters as IE has.

Some hard core OSS advocates, such as those who support Free software over OSS, may choose not to adopt Chrome because of "false claims towards openness" (Matthews, 2011), however their numbers are very small and their arguments about software freedom are often too difficult for the general public to comprehend or care about. People who are unaware what a browser is or that they can install a different browser than the one that came with their computer, will not appreciate the subtle differences in the FOSS argument.

Despite all these positive characteristics of OSS in the case of Chrome, it is not yet the top browser. It is less likely that outside companies will promote Chrome because it was not developed collaboratively, with participation of other firms in the way Firefox was. Since they do not have a stake in the success of Chrome, other companies may not be such strong supporters.

Like Firefox, Chrome will have to overcome the IE lock-in of enterprise companies who are hooked on Microsoft products for productivity tasks like documents and email communication. However, the ubiquity of Google's other products like search and maps combined with its improved features may help Chrome beat the convenience of Microsoft's complimentary products – something

that no other browser has achieved. But until Chrome comes pre-installed on new computers the way that IE does, it may not be able to overcome Microsoft's lock-in to become the standard Web browser.

Google has always pushed for compliance of open standards with Mozilla, forcing IE to abandon many proprietary HTML tags and follow W3C standards, which makes the Web better for everyone, especially Web developers. And it continues to promote open standards with Chrome. However, Google's primary motive for openness and standards may have been to ensure that it had direct access to user's browsers in order to sell ads (Waters, 2008).

While Google search and Google ads are available in any browser, other browsers determine the default search, and most users don't make an effort to seek alternatives. That is why "Chrome users are very valuable to Google", as Google senior vice president, Jeff Huber (2011) explains to industry analysts (para. 6). They are so valuable that Google almost doubled marketing expenses year over year, spending "over $1 billion on ads" in the first quarter of 2011 (Anthony, 2011, para. 5). Google chief financial officer, Patrick Pichette (2011), defends the significant increase in spending on Chrome marketing and advertising, explaining that "everybody that uses Chrome is a guaranteed locked in user for us in terms of having access to Google" (para. 6). Of course Chrome users are not trapped, and they are free to use other browsers and other search engines, but once they have the habit of using one browser, they tend to return to it (Claburn, 2011). Therefore, to increase ad revenues, it is in Google's best interest to ensure that more users choose Chrome as their default browser.

There may be other factors that motivated Google to enter the browser wars. Oshri et al. (2008) suggested that Microsoft's motive to win the browser wars was more about the battle over the operating system than just the browser; Microsoft wanted to merge browsing into its OS. There is suspicion that Google's motives for browser dominance may be connected to its new operating system, Chrome OS, which leverages cloud computing and threatens Microsoft's position as market leader in personal

computer operating systems (Dein, 2009). However others maintain that Google's primary motive is to ensure it has direct access to Web users to ensure that its advertising revenues are not redirected to competitors (Claburn, 2011). Yet others argued that Google needed to become the dominant browser so that it could have a strong position in Web technologies before jumping the next tech innovation wave into mobile. The companies that have the strongest network effects in desktop Web will make a more profitable leap into the next technology wave, mobile (Wu, 2010).

This case study confirms my theoretical prediction that Google chose to make Chrome OSS because it is the fastest and least expensive method to compete with an incumbent, adding strength to Perens (2005) economic argument for OSS. Because the browser is non-differentiating software for Google, sharing the code does not reveal any trade secrets and allows Google to benefit from the innovative ideas of many, not just the limited staff members working on the project. Furthermore, creating a successful OSS project that is competing with the browser standard is also good preparation for Google's transition into the mobile software market.

Case Study 2: OSS in the battle for the Smartphone

The browser war has spilled over into the battle for the smartphone. Open source veteran and former CEO of Mozilla, John Lilly (2011), writes that the reason for the fierce competition between Apple, Google and others is that "everyone is trying to move from the current wave of IT into the mobile one. Everyone is trying to become dominant, in order to take the wins from the network effects from the PC/Web battles and use them to win the next Mobile/Networked battle" (para. 7). The stakes are very high. A lot has been learned from the browser wars, but why did Google choose to make Android OSS?

Those critical of Google say that "the development of Android is perhaps the clearest example for the amount of resources Google is willing to invest in order to generate and get access to data for

expanding its second index; an entire communication infrastructure is being created that is optimized for gathering data and for delivering personalized services, which are yet another way of gathering more data" (Stalder & Mayer, 2009).

Smartphones are barely recognizable as phones – they are powerful pocket sized computers. Mobile phones began as clunky devices with large batteries and poor reception, used only to make phone calls when away from a landline. But as the hardware shrunk in size and the cellular networks grew, they became indispensable to people. However, they remained primarily for personal communications and email because small screen resolutions and slow data rates made Web browsing difficult and slow.

As the proliferation of Wi-Fi wireless hotspots and 3G networks made mobile browsing more feasible, mobile phones transformed into smartphones with sophisticated functionality and efficient operating system (OS) software. Mobile Internet usage was only 0.7% of all Internet usage in January 2009. With improved browsers and faster data transmission rates, mobile Web usage grew compared to that of desktop browsing, doubling year on year; with 1.6% in January 2010 and 4.3% in January 2011 ("Mobile Internet usage", 2012).

For years, RIM's BlackBerry was a market leader in smartphones, with free BlackBerry messenger, "superior battery life, network efficiency, security and best typing experience" (Thorston Heins in Miller, 2012). RIM failed to see the shift in user demand to consumer-oriented features like Web-browsing and apps, reducing the BlackBerry's share of new sales in global smartphone market from 21% in 2009, to only 11% in the third quarter of 2011 (Pettey, 2012). BlackBerry fell to fourth place in world sales by operating system in the fourth quarter of 2011 with only 8.8% compared to 50.9% for Android, 23.8% for Apple iOS and 11.7% for Symbian/Nokia (see Table 2).

Table 2
Worldwide Smartphone Sales to End Users by Operating System in Q4 for 2009-2011
(Thousands of Units)

Operating System	Q411 Units	Q411 Market Share (%)	Q410 Units	Q410 Market Share (%)
Android	75,906.1	50.9	30,801.2	30.5
iOS	35,456.0	23.8	16,011.1	15.8
Symbian	17,458.4	11.7	32,642.1	32.3
Research In Motion	13,184.5	8.8	14,462.0	14.6
Bada	3,111.3	2.1	2,026.8	2.0
Microsoft	2,759.0	1.9	3,419.3	3.4
Others	1,166.5	0.8	1,487.9	1.5
Total	149,041.8	100.0	101,150.3	100.0

Source: Gartner (Pettey, 2012)

Marketing hype and innovative new features on Apple's first smartphone, the iPhone, made it an instant success. Customers camped out days in advance at many of Apple's 164 retail stores in the U.S. when the iPhone first launched on June 29, 2007 ("Marketing the iPhone", 2007, para. 1). In many cases, stores could not keep up with demand and were forced to turn customers away. World sales figures have grown steadily as the iPhone becomes available in more countries. Apple's worldwide smartphone sales doubled from 2009 to 2010, however it didn't perform as well in terms of percentage market share, falling from third to fourth place.

Apple and Google were allies back in 2001, determined to limit Microsoft's market share and keep the company from dominating online services and mobile devices (Stone & Helft, 2010). But the relationship soured when Google began developing cellphones that Apple felt too closely resembled

the iPhone, and in early March, 2010, Apple filed a lawsuit against HTC, a manufacturer of Google's Android phones, claiming 12 copyright infringements (Bilton, 2010).

A late entrant to the smartphone market, Android powered over 52% of new smartphones sold globally in the third quarter of 2011 (Arthur, 2011). This compares to only 25.3% a year earlier, with the majority of the growth in China. In the U.S. alone, fourth quarter results for 2011 showed Android leading with 46.3% market share for newly activated smartphones, followed by iOS at 30%, BlackBerry at 14.9% and Windows at 4.6% (Nielsen, 2012).

As the browser wars have shown, controlling or influencing access to information on the Web is very valuable and worth fighting over because browsers can influence which ads a Web visitor sees. Google earned 97% of the $8.58 billion of revenue in the first quarter of 2011from advertising. While Google pays Firefox $85 million per year to be the default search engine for some 450 million Firefox users, the investment "directly translates into millions — and possibly billions — of dollars of revenue" (Anthony, 2011).

Proprietary control of a standard allows the standard owner to dictate the rules under which competitors can participate in the market and to extend the standard with proprietary add-ons (Oshri et al., 2008). The same holds true for the mobile Web. If Apple or BlackBerry holds a majority of the smartphone market, they could restrict or block Google from advertising on mobile networks, especially in app markets, favouring their own advertising networks. Mobile advertising is one of the fastest-growing revenue streams, with industry wide revenue projected to rise to $20.6 billion in 2015 from $3.3 billion in 2010 (Gartner, 2011). For a company reliant on advertising revenue to be locked out of the mobile Web market would be very costly.

Analysis: OSS characteristics of Android

Google's strategy is to ensure it is not blocked from mobile devices due to a dominant proprietary competitor that dictates access; it created an operating system using OSS and licensed it to mobile manufacturers at no cost (Android (operating system).2011). To determine why Google has chosen to make it OSS, Android will be analyzed with the theoretical framework developed by Oshri et al. (2008).

OSS origin

Android was developed in 2003 by Silicon Valley software veterans Andy Rubin, Rich Miner, Nick Sears, and Chris White, who were keen to make smarter mobile devices (Elgin, 2005). Android is based on the Linux kernel (Android Open Source Project, 2012), one of the most successful open source projects (Moody, 2001). Google purchased Android in 2005, bringing the founders on as staff. In November, 2007, the Open Handset Alliance (OHA), a group of mobile operators, handset manufacturers and software companies announced that it would accelerate mobile technology by developing Android, "the first complete, open, and free mobile platform" (Open Handset Alliance, 2007, para. 2). Led by Google, founding members of the OHA included Broadcom, China Mobile, eBay, HTC, Intel, LG, Marvell Technology Group, Motorola, Nvidia, Qualcomm, Samsung Electronics, Sprint Nextel, T-Mobile, Texas Instruments, and many others. The OHA currently has 84 members committed to the Android platform (*Open Handset Alliance.*2012). (See Appendix A for a full list of OHA members.)

Development sponsorship

Development continues to be led by Andy Rubin, the Android founder who joined Google when it purchased the product in 2005. He now holds the position of senior vice president of mobility. While

he is responsible for the product, he does not have the community status of a benevolent dictator, as with other OSS leaders.

The Android Open Source Project Web site welcomes contributions from individuals and organizations as contributors, developers, verifiers, approvers and project leads. But Google maintains tight control, taking responsibility for "product management and the engineering process for the core framework and platform" (*People and roles.*2012).

OSS program openness

While most sources report Android as OSS, I would characterize it as OSS with a leaning towards proprietary due to heavy corporate control. Google formed the OHA with a "commitment of openness", bringing together 84 technology and mobile companies "to accelerate innovation in mobile and offer consumers a richer, less expensive, and better mobile experience" (Open Handset Alliance. 2012). However, the Android platform has been accused of not really operating in an open manner, nor is it strictly maintaining open source. Former T-mobile and Apple executive, Leslie Grandy (2010) writes that many Alliance members, attempting to gain a competitive market advantage are "developing proprietary user experiences, which they are not contributing back into Android—as is standard for open source projects" (para. 3). Grandy further reported that according to an unnamed OHA member, the group is just a front for Google to make it appear as though Android is community driven with plenty of cross-industry support, but that it is primarily driven by Google staff. While Google has not responded, comments below the article highlight facts that the core Android applications – GMail, Maps, Calendar, Talk and Market – are not open source (ASM, 2010). Another user comments that if you "bear in mind Google's agenda is to push their Web services on mobile then all things become logical" (bonelyfish, 2010). All of Google's Web services include Google Ads, which are the primary revenue source for Google.

Android is not developed openly the way that Linux is built with community input. Speaking at a developer conference, Rubin stated that "Android is light on the community-driven side and heavy on open source" (Andy Rubin in Shankland, 2011, para. 4). The code is developed in private but once it is released, people can examine the source code, modify it, and build it into their own hardware, which Rubin says qualifies it as open source software. Google defends its actions saying that developing in private speeds up the development process and creates a more stable product for the consumer. However, many developers are frustrated by the delays and lack of transparency. For example, when Motorola's Xoom tablets were shipping with Android version 3.0 and 3.1, Google had not yet released the source code, and they may never release it (Shankland, 2011).

Free software advocate Richard Stallman (2011) characterizes Android as the most open choice in the mobile competition, but criticizes Google for withholding two recent releases of source code. He speculates that Google may make Andorid proprietary, and wonders if the only reason it was open in the beginning was to benefit from public input. Google claims it withheld these two releases because they were buggy and not stable for users, however Stallman argues that the user should be able to make that choice. Furthermore, Stallman says that a community member could contribute to fixing the bugs and improving the software, if they had access to it.

OSS program's compatibility

Because Google does not own the hardware it is used on, maintaining compatibility of Android on various handsets is a challenge. In order to remain competitive as a mobile operating system, Android must add new features, like voice dialing or VOIP support, however these features functionality also depends on the hardware available. On the other hand, the Android software drives standards, forcing hardware manufacturers to choose if it wants to be compatible with Android. It appears that hardware manufacturers have the opportunity to influence compatibility features by

participating in the Open Handset Alliance, however it is reported that Google leads the alliance, with little input from members ("Open Handset Alliance", 2012).

Android has been developed to run on a variety of hardware devices made by manufacturers including HTC, Samsung and Nexus. The Android Compatibility Program sets standards to ensure that independent developers can create apps that will work across all hardware certified as compatible ("Android compatibility", 2012), but it is up to the manufacturer to join the program or not. Complicating the matter further, the operating system is often customized by the handset maker or the mobile carrier, offering specific services to differentiate the product. There are multiple chipsets and multiple radio bands for multiple countries. Updates also need to be recertified by mobile carriers, i.e. Bell, Telus or Rogers, which takes more time. This fragmentation makes it far more complex to update the operating system for compatibility with all Android devices concurrently (Shanklin, 2011).

Price of OSS program

Android is a free operating system, as in there is no cost to download and use it. Google does not charge a fee for the software. But due to claims by Microsoft that Android OS violates a number of patents it holds, Android handset makers such as Samsung, Acer and HTC have negotiated to pay royalties of $3 to $6 per phone to Microsoft. A Goldman Sachs analyst estimates that Microsoft will earn $444 million in 2012 from these new agreements (Yarrow, 2011).

Availability of support for OSS program

A wide variety of hardware devices can run Android OS, making it more difficult to provide support for software upgrades to the operating system on all platforms. A Motorola executive explained that Google focuses on the compatibility with the latest hardware to ship, and that "the rest of the ecosystem doesn't see [the new OS] until you see it" (Christy Wyatt in Sagen, 2012, para. 4). Manufacturers of previous versions of handsets only see the new OS when it is released to the public.

Both the carrier and the manufacturer must work together to provide customers with upgrades, which is very time consuming. Figure 4 (below) shows that many Android devices are shipped with outdated operating systems and are slow to receive updates. Support is much further behind compared to the less fragmented Apple devices. The dashed line in Figure 4 indicates support updates. This shows that 11 of the 18 Android phones released in the United States after July 2010 stopped getting any security updates less than a year after their release, and none received updates up to the end of their two year contract (Degusta, 2011). The situation in Canada would be far worse as the standard mobile contract length is three years, compared to only two years in the U.S. This also makes it harder for developers to develop apps that function properly across all devices. They are forced into targeting an outdated OS version in order to maximize market reach.

Despite all of these challenges, most users are content with the operating system that ships with their handset and the negative comments of Android fanatics don't seem to be having an impact on the volume of new purchases.

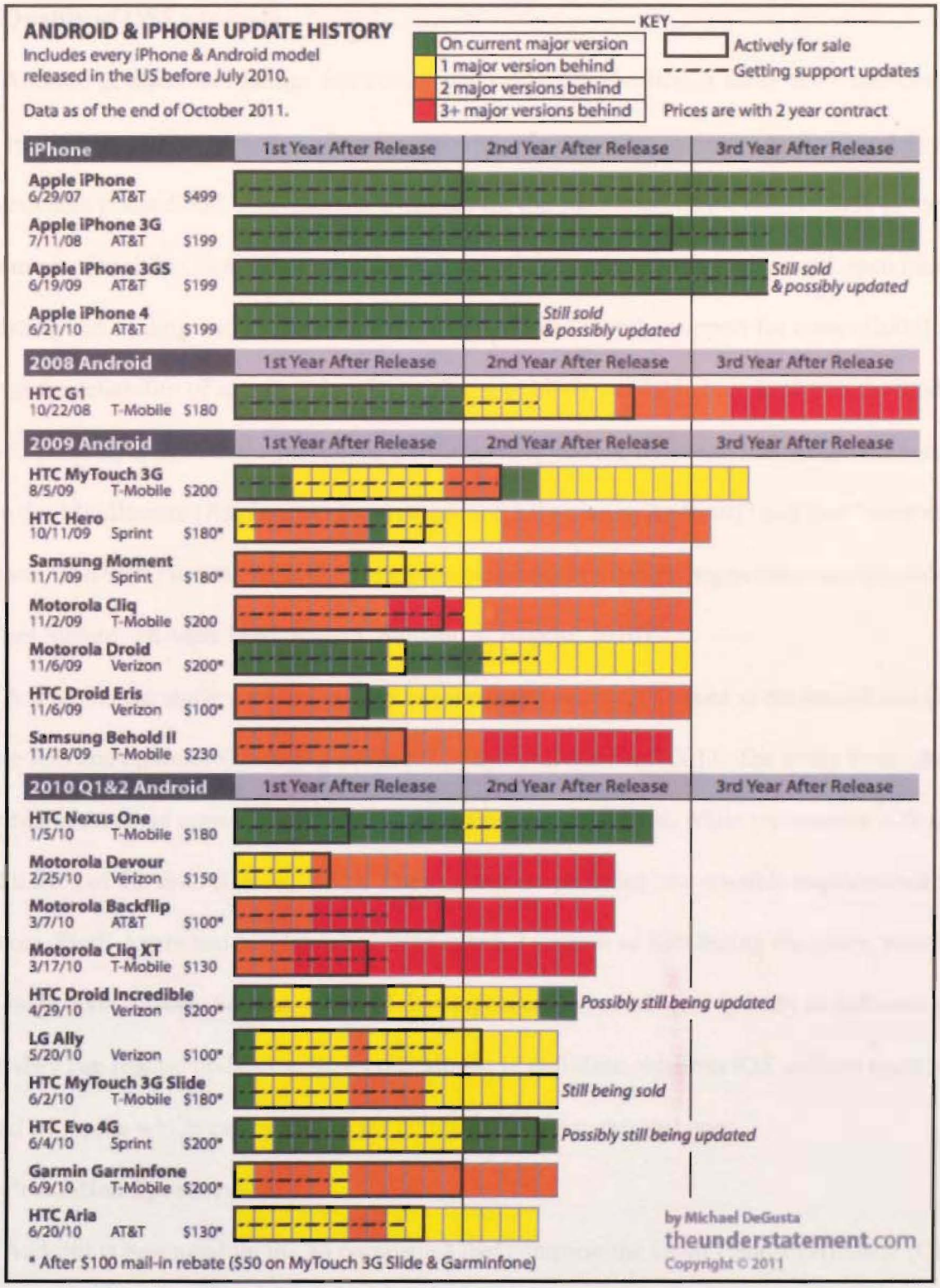

Figure 4. A visualization of support for Apple and Android devices for 3 years after release. This shows that Apple has supported OS 4.x upgrades for all versions of the iPhone up to 4S, while Android handsets are rarely supported with the latest Android OS, even within the first year of activation.

Quality of OSS program

Android gets positive ratings from computer science academics. A study at Purdue University looked specifically at the reliability of open source mobile operating systems, Android and Symbian. The researchers praised both Android and Symbian for the contributions they have made to the advancement of mobile OS development for their "well-defined and well-maintained open mechanisms for reporting and dealing with bugs", but they also cautioned that the support for customizability has an impact on the reliability of mobile OSes. By studying publicly available bug databases the study found that the "kernel layer in both the platforms are sufficiently robust, however, much effort is needed to improve the Middleware (Application Framework and Libraries in Android)" and that "most of the bugs (more than 90%) in both these platforms are permanent in nature, suggesting that the codebases are not yet mature" (Kumar Maji, Kangli, Sultana, & Bagchi, 2010).

A more recent study comparing OSS to proprietary software looked at crashes of mobile apps on Apple iOS and Android OS during the first 15 days of December, 2011. The study found that the top quartile of Android apps crashed 0.15% of the time they launched, while top quartile iOS apps crashed 0.51% of the time (Geron, 2012). The researchers provided two possible explanations for these differences. First, Apple had just launched their new 5.0 version of iOS during the study, which had several bugs upon release. Second, Android developers can respond more quickly to software errors because they can release updates to their code almost in real-time, whereas iOS updates must be approved by Apple which can take days for an update to get to the end user.

Promotion Sponsorship

Android is promoted by the 84 companies that comprise the Open Handset Alliance (OHA). They represent some of the largest mobile providers in the world with markets that dwarf the entire population of North America. One OHA member, China Mobile, has over 616 million mobile

customers that they can convert to smartphones, while the combined population of Canada and the United States is only 346 million (O'Reilly, 2012). Android offers China Mobile with a low cost solution to upgrade many of these customers to affordable smartphones. And the figures have shown that China is activating more handsets with Android OS than any other mobile OS. With a large number of companies promoting the adoption of Android via the OHA, it is not surprising to see that Android is the most popular smartphone OS in the world.

Strategic option

Android is succeeding globally by providing a free, customizable operating system that functions on a wide range of devices in any language, allowing other companies to join forces in the smartphone market competition. Android offers similar features compared to quality and reliability, plus it can be bundled with Google's very popular Web services such as Google Maps, Gmail, Google Docs (Document, Spreadsheet, Form, Presentation, etc.), YouTube and Web developer tools, which help to lock-in the customer. This integration gives users a seamless experience across the Web and provides Google with a strong competitive advantage.

Discussion

Most mobile consumers do not think about their smartphone choice in terms of operating system. They are more likely drawn by feature rich handsets that maximize communication options at a price that is reasonable. However many consumers are tied to contracts with mobile carriers (Bell, Rogers, Telus, etc.) and are forced to choose one of the handsets offered by the carrier rather than look at all the options in the market. Advertising, marketing and word of mouth certainly play a role in these decisions as well. Apple's iPhone, with the rich selection of apps is very appealing to most consumers, but the expensive monthly plans may take it out of reach financially. RIM's BlackBerry was the enterprise choice for over a decade but a poorer selection of apps makes it less appealing as a personal

communication device. Nokia has also been a mobile leader with feature rich handsets appealing to personal customers, especially in Europe. But it has struggled to evolve its mobile OS to deliver the smartphone features required to compete with the iPhone. But Google's Android OS puts handsets from HTC, Samsung and others in the same market as iPhone, BlackBerry and Nokia. Devices powered by Android are complimented by the Android app market that is competing with Apple's App Store. OSS enthusiasts and hackers may prefer Android as it is easier to extend with custom programs since the OS is open to them. But for the average consumer, the primary appeal of Android is as a more affordable, feature-rich smartphone.

However, the question of this case study is to determine why Google chose to make Android OSS and not proprietary. This case study found that the advantages of making Android OSS are:

1. A free codebase that was modified to meet its needs rather than starting from scratch.
2. Experienced in-house talent that had contributed heavily to OSS projects including Chrome and Firefox.
3. The open license makes it attractive for firms to participate in the standard's development and promotion.
4. Having 54 other companies involved in creating the operating system has helped it to become the standard globally.
5. Bundling with Google services can lock-in customers.

The fact that Android is OSS has some negative implications that may affect Android's market share in the future.

1. Because each sponsoring company is involved for different reasons (mobile operators to sell subscriptions, handset manufacturers to sell hardware, semiconductor companies to

sell chips, software companies to sell services and commercialization companies to sell consulting services) some will become competitors after the development phase.

2. Because of the wide range of hardware, program compatibility may become an issue in the future.

3. Any Android distribution can be forked, meaning that the development of the OS branches off in a different direction from the parent project. These forked developments can then block all of Google's services, as is the case with Kindle Fire (Burrows, 2010).

Mobile Web traffic is still low, but growing rapidly, making it an important platform for future advertising. Google doesn't earn commission from any Android handsets sold, but it does take a 30% cut of all revenues from apps sold in the Android Store and will likely take a similar percentage with features like Google Wallet that will allow software developers to accept payments within apps (Android (operating system).2011).

A mobile analyst claims that "part of the reason Android is so important as an operating system is that it lets Google put its mobile services front and center" (Ken Sena in Burrows, 2012). It is expected that mobile apps will increasingly be the preferred method for search, rather than browser-based search. This would be a significant loss to Google if the only method for reaching apps was via Apple's App Store. But with the success of the Android market, Google is guaranteed access to advertising revenues on apps as well.

This case study shows that by making Android OSS, Google had a fast and inexpensive method for delivering its services across many manufacturers. This ensured that Google could have a preferred position for search on most Android handsets and that Google would not be blocked from app advertising revenue on the mobile market. OSS has allowed Google to create a flexible mobile OS that

meets the needs of many manufacturers, allowing them to work together to defeat the standard mobile OS.

However, it is very early in the smartphone competition to be declaring a victory. This case study highlights many issues with Android as OSS that may threaten Google's position in the future. One of the largest issues may be the inability to control quality due to the range of hardware available from dozens of manufacturers and the inability to provide software updates to all the versions. Another issue for concern is that one of the manufacturers could fork the Android OS and develop new versions that are exclusive to another advertising network and a different app store, blocking Google from the new network. But, this case study also highlights that OSS provided Google with the fastest and least expensive way to enter the smartphone market, strengthening Perens' (2005) economic argument for OSS.

While I remain suspicious of Google's motives, I am pleased to see that it is creating competition on the mobile Web and for mobile apps, so that one company does not set standards that stifle innovation and choice on the Web, the way that Microsoft did during the browser wars. OSS allowed Google and members of the OHA to join forces to create a layer of competition and keeping the development open and accessible for all. However, this study does draw attention to the fact that Google could become the next Microsoft. With such huge profits at stake, it may begin controlling access to communications networks in order to favour its own services.

Limitations of this study

The case study methodology was based on a model utilized by a well-funded team of academics with the ability to complete primary research. Due to the limited scope of this paper, the data gathered in this report was restricted to textual research: books, review of other studies, news archives, blogs, user forums, etc. It points to two potential weaknesses of the study.

1. Bias: Due to lack of primary research, the conclusions are limited to facts that others found interesting enough to report and share or that were readily available. Since many of the sources come from the private sector, there may be a bias in the favouring corporate interests.
2. Weak conclusions: Two of the nine categories: availability of support and quality of OSS program; would benefit greatly from quantitative research, offering stronger conclusions rather than vague generalizations.

Despite the limits of this study, the literature review and qualitative data do provide some answers as to why Google chose to make Chrome and Android as OSS.

Conclusion

OSS is a complex subject with many opposing opinions as to what makes it appealing. This paper found several reasons why Google may have chosen to make two software products, the Web browser Chrome, and the mobile OS, Android, as OSS. Most notably, OSS increased the speed and reduced the cost of developing two large projects. These case studies have added strength to Perens' economic argument that OSS "is more efficient than other economic paradigms of software development for producing software that does not differentiate its user's business" (Perens, 2005, para. 6). Plus, Google was able to leverage an active community of OSS supporters who have become advocates for these products.

This paper has highlighted that OSS is gaining ground against proprietary software and is being used as a tool to help corporations ride the waves of innovation. Computer pioneer IBM struggled to keep up with the technology jump to personal computing from the mainframe market it once controlled. But it survived by embracing OSS in the late 90s to compete with Microsoft. And now Microsoft has begun developing OSS platforms to increase its competitive edge in cloud services.

Microsoft's chief open source strategist exclaims that "when your competitors start to use it, you have to too" (Metz, 2012). The share of proprietary software in the world is shrinking because open source alternatives are faster and less expensive to develop. People may one day look back at this relatively short history of software development as the dark ages, when innovation was stifled by proprietary interests. Google is unique because it is embracing OSS before its business is failing. It will be interesting to see if other companies follow its lead.

It is important to remember that Google did not develop Chrome and Android as OSS for altruistic reasons. Google created an index of the Web that helps us to find information online. But it also has a second index that tracks user behaviour which it sells to advertisers. Google benefits from network effects with the value of its index dependant on the number of people using its products (Weber, 2004). Therefore it is in Google's best interest to always be building the size of its network and to stimulate innovation on the Web, not for the benefit of humanity, but to grow its profits.

This paper has confirmed that OSS is positive in stimulating innovation and creativity on the Web, however there is concern that many citizens may focus on the "open" in open source and see Google's adoption of OSS as a sign that it is open and transparent with its handling of user data. While this paper only hints at this issue, it is certainly an area that requires deeper study. Google's OSS projects are tightly controlled by staff and do not develop the user community or benefit from the eyes and ideas of millions as much as projects like Mozilla or Linux do. But Google does share its code, which helps to develop the ecosystem which should help to speed the development of software, allowing the knowledge economy to reach a higher potential of the hardware resources available today. Google's motives have always been clear: it wants more people using the Internet and making more searches so that it can sell more ads. Google's large share of the browser and mobile OS markets via Chrome and Android means that it has even more control over the way we access information. There is reason to be

concerned about the size of Google and the amount of control that it has over our personal communications. Google critic, Siva Vaidhyanathan (2011) warns that most people are unaware of Google's power because it is currently acting as a benevolent dictator, so the negative consequences seem minor compared to the many benefits.

We learned from the browser wars that when one corporation mediates access to the network, it may favour its own services and stifle innovation. With these two OSS products, Google has threatened Microsoft's browser standard and weakened Apple's mobile OS standard. OSS may restrict Google from adopting this type of service favouring on its own platform, because it depends on the support of partners to remain the dominant standard. If Google stops responding to the needs of the other partners, the partners can fork the OSS and develop the product independently. However, forks can lead to fragmentation, weakening the network effects of the platform. Nevertheless the threat of a fork may motivate Google to continue innovating and restrict it from favouring its own services.

Google has made it easier for us to find academic articles, talk to our friends, find ourselves on maps, and more (Vaidhyanathan, 2011). Now it is improving software development by sharing its advances with the world. However, it is imperative that we remember that Google is a for-profit business and it will always make decisions based on what is best for its bottom line, not what is best for society. So while the consequences of Google using OSS seem positive, it is important that more researchers continue to question the motives of the corporations that control our communications, ensuring that they remain open and accessible to all.

Appendix A – Members of the Open Handset Alliance

Mobile Operators

- Bouygues Telecom www.bouyguestelecom.fr Created in 1994, Bouygues Telecom provides mobile, fixed, TV and internet communications services to the French customers.
- China Mobile Communications Corporation www.chinamobile.com/en
- China Telecommunications Corporation en.chinatelecom.com.cn China Telecommunications Corporation (China Telecom) is an extra-large State-owned telecom operator in China. China Telecom mainly provides the integrated information services including the fixed-line telephone, mobile service, satellite communications services, Internet connection and applications services,etc.
- China United Network Communications www.chinaunicom.com China Unicom is the only Chinese telecom operator listed on the stock exchanges in New York, Hong Kong and Shanghai. On 7 January 2009, China Unicom was granted a WCDMA license.
- KDDI CORPORATION www.kddi.com KDDI is a telecommunication operator that provides wide-ranging services from mobile to fixed in Japan.
- NTT DOCOMO, INC. www.nttdocomo.com NTT DOCOMO is the world's leading mobile communications operator, with 53 million customers, of which 40 million use the 3G/ FOMA service based on W-CDMA technology.
- SOFTBANK MOBILE Corp. mb.softbank.jp/mb/en SOFTBANK MOBILE Corp. is a leading mobile operator in Japan with over 19 million customers and a member of the SOFTBANK Group. (as of 31 October 2008)
- Sprint Nextel www2.sprint.com/mr/aboutsprint.do Sprint Nextel offers a comprehensive range of wireless and wireline communications services including the fastest and largest national mobile broadband network, a broad portfolio of devices and an wide array of applications, which enable customers to do the things that matter the most to them instantly and on the go – at SprintSpeed™.
- T-Mobile www.t-mobile.net Serving more than 112 million mobile customers in Europe and the U.S., T-Mobile is one of the world's leading companies in mobile communications, and the mobile telecommunications subsidiary of Deutsche Telekom AG (NYSE: DT)
- Telecom Italia www.telecomitalia.it Supplying 34.3 mobile lines, around 23 million landlines and 7.3 million broadband clients, Telecom Italia is a Italy's leading ICT enterprise with a significant international presence in Europe and South America. The Group trades through pre-eminent brands Telecom Italia, Alice, TIM, La7, MTV Italia, APCom and Olivetti in fixed-line and mobile telecommunications, Internet and media, office & system solutions.
- Telefónica www.telefonica.es Telefónica is one of the largest telecommunication companies in the world, providing communication, information and entertainment solutions, with presence in Europe, Africa and Latin America and with more than 212 million clients of fixed and mobile services.
- TELUS www.telus.com TELUS is a leading national telecommunications company in Canada, providing a wide range of communications products and services including data, Internet protocol (IP), voice, entertainment and video.

- Vodafone www.vodafone.com Vodafone is the world's leading international mobile communications group with approximately 280 million proportionate customers as of 30 September 2008. Vodafone currently has equity interests in 27 countries across five continents and over 40 partner networks worldwide. For more information, please visit www.vodafone.com.

Handset Manufacturers

- Acer Inc. www.acer-group.com Acer ranks as the world's No. 3 vendor for total PCs and No. 2 for notebooks, with the fastest growth among the top-five players. Revenues in 2008 reached US$16.65 billion.
- Icatel mobile phones www.alcatel-mobilephones.com Alcatel mobile phones offer eye-catching handsets, with unique designs at competitive prices. ALCATEL handsets are managed by TCT Mobile, who is part of TCL Communication listed on the Hong Kong Stock Exchange (HKSE: 2618).
- ASUSTeK Computer Inc. www.asus.com ASUS is a leading company in the new digital era for IT and communication products. The company's turnover for 2007 was 6.9 billion U.S. dollars.
- CCI www.compalcomm.com Innovated, 1st tier qualified and fast track for smartphone design and integration, mass production in competitive cost and completely cover WCDMA/CDMA/TD-SCDMA wireless technologies.
- Dell www.dell.com Dell listens to customers and uses that insight to make technology simpler, reliable, and deliver long-term value.
- Foxconn International Holdings Limited www.fih-foxconn.com/home/default.aspx FIH is the global leader in the handset and wireless communications manufacturing and service.
- FUJITSU LIMITED www.fujitsu.com Manufacturing and sales of telecommunication systems, information processing systems and electronic devices, and providing services related to these systems.
- Garmin International, Inc. www.garmin.com Garmin is the global leader in satellite navigation and has built millions of products that serve the automotive, wireless, OEM, fitness, aviation and marine markets.
- Haier Telecom (Qingdao) Co., Ltd. mobile.haier.com Haier Mobile is one of leading provider in handset design, manufacturing and service in China.
- HTC Corporation www.htc.com HTC Corporation focuses on driving cutting-edge innovation into a wide variety of mobile devices to create the perfect match for individuals. The company is listed on the Taiwan Stock Exchange under ticker 2498.
- Huawei Technologies www.huawei.com Huawei Technologies is a leader in providing next generation telecommunications network solutions for operators around the world.
- Kyocera www.kyocera.com Kyocera is a 50 year old, $13 billion company with 190 businesses worldwide, all working to develop products that improve customers' lives. Kyocera's wireless devices --found worldwide from Japan to the US - utilize the latest technology advancements to provide great value.
- Lenovo Mobile Communication Technology Ltd. www.lenovomobile.com Lenovo Mobile Communications is one of the leading integrated mobile communication and information service providers in China.

- LG Electronics, Inc. www.lge.com LG, the brand that is Delightfully Smart, is a global leader and technology innovator in consumer electronics, home appliances and mobile communications. LG's vision is to supply top-of-the-range innovative digital products and services and ensure customer satisfaction.
- Motorola, Inc. www.motorola.com Motorola is known around the world for innovation and leadership in wireless and broadband communications.
- NEC Corporation www.nec.com NEC Corporation is one of the world's leading providers of networking, mobile communications and information technology.
- Pantech www.pantech.com Pantech is a worldwide mobile company, leading the global mobile market by offering new values for customers with innovated technologies.
- Samsung Electronics www.samsung.com A leading innovator and provider of mobile phones and telecom systems.
- Sharp Corporation sharp-world.com Sharp Corporation is a worldwide developer of innovative products and core technologies that play a key role in shaping the future of electronics. In the mobile phone business, in 2000 Sharp became the first company in the industry to introduce a camera-equipped mobile phone that enables users to instantly e-mail photos taken with the built-in camera.
- Sony Ericsson www.sonyericsson.com Sony Ericsson is a top global mobile phone manufacturer with sales of over 100 million phones in 2007. With operations in over 80 countries, Sony Ericsson was established as a 50:50 joint venture by Sony and Ericsson in October 2001. For more information about Sony Ericsson, please visit www.sonyericsson.com.
- Toshiba Corporation www.toshiba.com Toshiba is a world leader and innovator in pioneering high technology, a diversified manufacturer and marketer of advanced electronic and electrical products spanning information & communications equipment and systems.
- ZTE Corporation www.zte.com.cn ZTE is a leading global provider of telecommunications equipment and network solutions. It has the widest and most complete product range in the world – covering virtually every sector of the wireline, wireless, service and terminals markets.

Semiconductor Companies

- AKM Semiconductor Inc www.akm.com AKM Semiconductor is a leading supplier of mixed-signal ICs for consumer and communications applications. Devices for mobile phones include audio products and electronic compass ICs.
- Audience www.audience.com Audience is a voice processor company that enables clear communications anywhere with noise suppression technology based on the intelligence of the human hearing system.
- ARM www.arm.com ARM designs the technology that lies at the heart of advanced digital products, from wireless, networking and consumer entertainment solutions to imaging, automotive and storage devices.
- Atheros Communications www.atheros.com Atheros Communications is a leading developer of wireless system solutions for communications products. The company's technology is used by leading PC, networking equipment and CE device manufacturers.
- Broadcom Corporation www.broadcom.com Broadcom Corporation is a major technology innovator and global leader in semiconductors for wired and wireless communications, providing products that enable the delivery of voice, video, data and multimedia to and throughout the home, the office and the mobile environment.

- CSR Plc. www.csr.com CSR is the leading provider of GPS enabled location platforms for mainstream markets with focus on wireless, automotive, consumer electronic and mobile compute devices.
- Cypress Semiconductor Corporation www.cypress.com Cypress's programmable solutions add power, style, and performance to multimedia handsets. Offerings include PSoC®-based touch - sensing solutions, USB and memories.
- Freescale Semiconductor www.freescale.com Freescale Semiconductor is a global leader in the design and manufacture of embedded semiconductors and a leading provider of ICs for smart mobile devices.
- Gemalto www.gemalto.com Gemalto, the leader in digital security, provides solutions designed to make personal digital interactions more convenient, secure and enjoyable.
- Intel Corporation www.intel.com/products/mid Intel, the world leader in silicon innovation, develops technologies, products and initiatives to continually advance how people work and live.
- Marvell Semiconductor, Inc. www.marvell.com Marvell is a leader in development of storage, communications, and consumer silicon solutions with a diverse product portfolio that powers the entire communications infrastructure from enterprise solutions to mobile consumer devices.
- MediaTek, Inc. www.mediatek.com MediaTek Inc. is a leading fabless semiconductor company for wireless communications and digital multimedia solutions, also a pioneer in cutting-edge SOC system solutions for wireless communications, high-definition TV, optical storage, DVD and Blu-ray products.
- MIPS Technologies, Inc. www.mips.com MIPS Technologies is a leading provider of industry-standard processor architectures and cores that power some of the world's most popular products for the home entertainment, communications, networking and portable multimedia markets.
- NVIDIA Corporation www.nvidia.com/page/handheld NVIDIA is the worldwide leader in visual computing technologies. Its Tegra family of computers-on-a-chip deliver rich multimedia features including 3D graphics and high definition video for next generation mobile devices including smartphones and personal media players.
- Qualcomm Inc. www.qualcomm.com Qualcomm Incorporated is a leader in developing and delivering innovative digital wireless communications products for advanced devices around the world.
- Renesas Electronics Corporation www.renesas.com Renesas Technology is the world's No.1 supplier of microcontrollers, as well as a leading provider of Power MOSFETs, System-on-Chip (SoC), and more.
- ST-Ericsson www.stericsson.com ST-Ericsson is an industry leader in design, development and creation of mobile platforms and wireless semiconductors. Through cutting-edge innovation backed by a complete portfolio and a dedicated partnership approach towards customers, ST-Ericsson is a key supplier to four of the industry's top five handset manufacturers.
- Synaptics, Inc. www.synaptics.com Synaptics, Inc., providing easy-to-use interface solutions for mobile phones, personal media players, notebooks and PC peripherals, supplies a variety of user input solutions for mobile devices that make accessing digital content easy and fun.
- Texas Instruments Incorporated www.ti.com/wirelessresources TI is a leading manufacturer of wireless semiconductors, delivering the heart of today's wireless technology and building solutions for tomorrow.

- Via Telecom www.via-telecom.com VIA Telecom is one of two CDMA baseband chipset providers worldwide, offering comprehensive chipset solutions including software packages and mature turn-key designs. Its innovative solutions for CDMA have been adopted by many handset companies, including Nokia and Samsung, and successfully commercialized on the networks of principal CDMA carriers.

Software Companies

- Ándago Ingeniería S.L. www.andago.com Andago provides fully interoperable ecosystems based on Open Source and PaaS technologies for mHealth, eGovernment, eTourism, and Smart Energy Systems.
- ACCESS CO., LTD. www.access-company.com ACCESS is a global company providing leading technology, software products and platforms for Web browsing, mobile phones, digital TVs and other networked devices.
- Ascender Corp. www.ascendercorp.com/oha.html Ascender Corp. is a leading provider of advanced font products and innovative applications for mobile devices.
- Cooliris, Inc. www.cooliris.com Cooliris creates products that transform the browsing experience across screens, making discovering and enjoying media more exciting, efficient, and personal.
- eBay Inc. www.ebay.com
- Google Inc. www.google.com Our mission is to organize all the world's information and make it universally accessible and useful.
- LivingImage LTD. www.livingimage.jp A unique company that consists of renowned engineering, marketing and creative experts in the audio visual arena.
- Myriad www.myriadgroup.com Myriad is a leading provider of multi-media solutions and end-to-end integration services that accelerate time-to-market and reduce operational costs for OEMs and Operators.
- MOTOYA Co., Ltd. www.motoya.co.jp MOTOYA is leading company for Japanese digital fonts. Our products are outline fonts (TrueType, OpenType, etc.) and bitmap fonts.
- Nuance Communications, Inc. www.nuance.com Nuance Communications (NASDAQ: NUAN) is a leading provider of speech and imaging solutions for businesses and consumers around the world.
- NXP Software www.software.nxp.com NXP Software is the market leader in innovative multimedia solutions, its LifeVibes software is used in over 650M mobile devices today.
- OMRON SOFTWARE Co, Ltd. www.omronsoft.co.jp OMRON SOFTWARE, a leading embedded device software company, provides innovative / universal language and image processing technologies for mobile devices.
- PacketVideo (PV) www.pv.com PacketVideo (PV) is a multimedia software company whose software powers the world's leading mobile entertainment services, including Verizon Wireless' VCAST music and video services, NTT DoCoMo's 3-G FOMA service and Orange World by Orange.
- SkyPop www.skypop.com Next generation services for mobile devices.
- SONiVOX www.sonivoxrocks.com SONiVOX is a premier developer of audio technologies and solutions that empower consumers to create Sound That Rocks.

- SVOX www.svox.com SVOX, a leading supplier of embedded speech solutions, drives adoption of speech user interfaces in automotive and mobile device industries.
- VisualOn Inc. www.visualon.com VisualOn's multimedia framework and optimized codecs are compatible with Android to enable the best multimedia experience for Android devices.

Commercialization Companies

- Accenture www.accenture.com Accenture is a global management consulting, technology services and outsourcing company, with approximately 211,000 people serving clients in more than 120 countries.
- Aplix Corporation www.aplixcorp.com Aplix Corporation enables mobile handset manufacturers to have a faster, lower development cost and lower risk route to deploy wireless Java solutions
- Borqs www.borqs.com Borqs provides best-in-class operator-centric mobile handset operating system (OS) software products and mobile internet service platforms and solutions.
- Intrinsyc Software International www.intrinsyc.com Intrinsyc provides hardware, software, and service solutions that enable companies to build next-generation mobile and embedded products.
- L&T Infotech www.lntinfotech.com A leading software services provider, L&T Infotech offers its comprehensive suite of Product Engineering Services to the Telecom industry globally.
- Noser Engineering Inc. www.noser.com/oha Noser Engineering Inc. - core contributor of the Android Platform is your integrator and customization partner.
- Sasken Communication Technologies Limited www.sasken.com Sasken works with Handset OEMs and Semiconductor companies to enable differentiated devices and user experiences. We offer an unique combination of R&D Consultancy, Wireless Software Products, Software and Hardware Services.
- SQLStar International Inc. www.sqlstar.com Embinux Group of SQLStar provides system integration, customer engineering services and custom apps. for Android and embedded-Linux on MSM & OMAP platforms.
- TAT - The Astonishing Tribe AB www.tat.se TAT - The Astonishing Tribe - a specialist in mobile user interfaces, recognized for its design capabilities and for its software solutions that enable richer user experiences on any platform, to date embedded in more than 140 million devices.
- Teleca AB www.teleca.com Teleca is a global supplier of innovative software and solutions to mobile communications companies. Teleca has about 2,000 employees in Asia, Europe and North America.
- Wind River www.windriver.com/oha Wind River enables companies to develop, run, and manage device software faster, better, at lower cost and more reliably.
- Wipro Technologies www.wipro.com/services/pes A leading Software Services Company and #1 provider of integrated business, technology and process solutions, globally

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