Acknowledgements

I am very happy to bring you this wonderful Operating System that is on the docks right now. However no work can be done without help. For this effort would have gone to waste had not Google posted such detailed videos on Youtube. I am also grateful to my teachers for their help and support. Last but not the least I thank my parents for lending me their hand. To all those involved, I, on behalf of all my team members, thank you.

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Introduction

Google Chrome OS is a Gentoo Linux-based operating system designed by Google to work exclusively with web applications. Google announced the operating system on July 7, 2009 and made it an open source project, called Chromium OS, that November. Unlike Chromium OS, which can be compiled from the downloaded source code, Chrome OS will only ship on specific hardware from Google's manufacturing partners. The user interface takes a minimalist approach, resembling that of the Chrome web browser. Because Google Chrome OS is aimed at users who spend most of their computer time on the Internet, the only application on the device will be a browser incorporating a media player.

The expected launch date for retail hardware featuring Chrome OS has slipped since Google first announced the operating system: from late 2010 to mid-2011.
History

Google developers began coding the operating system in 2009, inspired by the growing popularity and lower power consumption of netbooks and the focus of these small laptops on Internet access. To ascertain marketing requirements for an operating system focused on netbook Web transactions, the company did not do the usual demographic research generally associated with a large software development project. Instead, engineers have relied on more informal metrics, including monitoring the usage patterns of some 200 Chrome OS machines used by Google employees. Developers also noted their own usage patterns. Matthew Papakipos, former engineering director for the Chrome OS project, put three machines in his house and found himself logging in for brief sessions: to make a single search query or send a short email.

On November 19, 2009, Google released Chrome OS's source code as the Chromium OS project. As with other open source projects, developers are modifying code from Chromium OS and building their own versions, whereas Google Chrome OS code will only be supported by Google and its partners, and will only run on hardware designed for the purpose. Unlike Chromium OS, Chrome OS will be automatically updated to the latest version. InformationWeek reviewer Serdar Yegulalp wrote that Chrome OS will be a product, developed to "a level of polish and a degree of integration with its host hardware that Chromium OS does not have by default," whereas Chromium OS is a project, "a common baseline from which the finished work is derived" as well as a pool for derivative works. The product and project will be developed in parallel and borrow from each other.

At a November 19, 2009 news conference, Sundar Pichai, the Google vice president overseeing Chrome, demonstrated an early version of the operating system. He previewed a desktop which looked very similar to the Chrome browser, and in addition to the regular browser tabs also had application tabs, which take less space and can be pinned for easier access. At the conference, the operating system booted up in seven seconds, a time Google said it would work to reduce.

Also on November 19, 2009, Chris Kenyon, vice president of OEM services at Canonical Ltd announced that Canonical "is contributing engineering to Google [Chrome OS] under contract. In our discussions, Sundar Pichai and Linus Upson made it clear that they want, wherever feasible, to build on existing components and tools from the open source community without unnecessary re-invention. This clear focus should benefit a wide variety of existing projects and we welcome it".

On January 25, 2010, Google posted notes, images and a video of a conceptual design showing how a Chrome OS user interface might look on a tablet PC with a 5-10 inch screen. The design would include the same basic layout as on netbooks, but with a touch interface; an onscreen qwerty keyboard in different layouts; large, square icons placed above the tabs; and panels placed along the bottom edge that could be opened with an upward dragging motion. The posting was made two days before Apple announced the iPad tablet. On March 16, 2011, several changes to Chromium OS were made which indicate the development of a tablet version of Google Chrome OS.

In March 2010, Google indicated that consideration is being given to developing two versions of the operating system, a consumer version and an enterprise version.
**Cr-48 prototype hardware**
The Cr-48 showing the "new tab" page which lists installed Chrome apps

At a December 7, 2010 press briefing, Google announced the Cr-48 laptop, a reference hardware design to test the Chrome OS operating system. The laptop's design broke convention by replacing the Caps lock key with a dedicated search key.

The Cr-48 is intended for testing only, and will not be sold to the general public. Google has addressed complaints that the operating system offers little functionality when the host device is not connected to the Internet. The company demonstrated an offline version of Google Docs running on Chrome OS and announced a 3G plan that would give Chrome OS users 100 MB of free data each month, with additional paid plans available from Verizon.

About 60,000 Cr-48s were manufactured to be distributed to testers and reviewers in early December 2010. Reviews published about the Chrome OS running on the Cr-48 in mid-December 2010 indicated that while the project holds promise it still has some distance to go before being ready for market.

In reviewing the Cr-48 on 29 December 2010, Kurt Bakke of Conceivably Tech said: "in my household the Chromebook has turned into a family appliance and the most frequented computer in our household. Its 15 second startup time and dedicated Google user accounts made it the go-to device for quick searches, email as well as YouTube and Facebook activities. It has not turned into a device that can rival the appeal of any of our other notebooks – we have one gaming laptop, two mainstream notebooks and two netbooks in our household with five kids. The biggest complaint I heard was its lack of performance in Flash applications."

On March 8, Google Product Management vice president Sundar Pichai stated that the last of the 60,000 Cr-48s had been shipped.

The CR-48 notebooks have additional unused hardware installed, for implementation at a future date. Among these components are a Bluetooth 3.0 Controller, an SD Card reader and a GPS Locator. At this time the USB port only acts as a keyboard, mouse or ethernet adapter port, but Google plans to implement support for USB storage. The USB port will not work as a printer port as there is no print stack on the operating system and adding additional hardware would cause problems with the operating system's "self knowing" security model. Users are encouraged to use a secure service called Google Cloud Print to print to legacy printers connected to their desktop computers, or connect an HP eprint printer to the Google Cloud Print service for software-free printer connection.
Reception

Ahead of the commercial launch of Chrome OS devices, industry observers have evaluated the operating system in terms of its potential success, advantages and limitations.

Early on, Chrome OS was viewed as a competitor to Microsoft, both directly to Microsoft Windows and indirectly the company's word processing and spreadsheet applications -- the latter through Chrome OS's reliance on cloud computing. But Chrome OS engineering director Matthew Papakipos argued that the two operating systems would not fully overlap in functionality because Chrome OS hosted is intended for netbooks, which lack the computational power to run a resource-intensive program like Photoshop.

Some observers claimed that other operating systems already fill the niche that Chrome OS is aiming for, with the added advantage of supporting native applications in addition to a browser. Tony Bradley of PC World wrote in November 2009: "We can already do most, if not all, of what Chrome OS promises to deliver. Using a Windows 7 or Linux-based netbook, users can simply not install anything but a web browser and connect to the vast array of Google products and other web-based services and applications. Netbooks have been successful at capturing the low-end PC market, and they provide a web-centric computing experience today. I am not sure why we should get excited that a year from now we'll be able to do the same thing, but locked into doing it from the fourth-place web browser."

A year later, Ryan Paul of Ars Technica came to similar conclusions. He wrote that Google's Cr-48 prototype "met the basic requirements for Web surfing, gaming, and personal productivity, but falls short for more intensive tasks". He praised Google's approach to security, but wondered whether mainstream computer users would accept an operating system whose only application is a browser. "In its current form, I think that the operating system could appeal to some niche audiences, like regular consumers users who really just need browsing or office productivity workers at companies that have gone Google or only use intranet apps. It's decidedly not a full-fledged alternative to the general purpose computing environments that currently ship on netbooks". Paul wrote that most of Chrome OS's advantages "can be found in other software environments without having to sacrifice native applications".

Wolfgang Gruener of Conceivably Tech noted the lack of support for Photoshop and comparable software, as well as what he called a "workable but annoying trackball design". His conclusion: "Google has a lot of work to do, but Chrome OS makes a lot of sense and if Google does not shoot itself in the foot, it could light the way to how mainstream computing will look like 5 or 10 years from now."

In ongoing long-term testing of the operating system on the Cr-48 hardware, Wolfgang Gruener of Conceivably Tech stated in January 2011: "cloud and SaaS computing is a frustrating and rather painful experience with the Cr-48 at basic cellular data speeds. Offline capability is non-existent in the Cr-48 and this experience clearly shows that the Cr-48 and Chrome OS needs considerable offline capability before this device and OS will go anywhere. Without offline features that include Google Docs and other basic apps including Grooveshark, Evernote or Pixlr, the Cr-48 turns into a useless brick when you are dealing with no or ancient Internet connections. I told you so, some readers may say, but nothing is like the real experience. So, Google, where is the offline support?"
In his continuing test in February 2011 Wolfgang Gruener of Conceivably Tech said: "If I was to describe my relationship status with the Cr-48 on Facebook, I’d have to choose [It's complicated]. It’s better on some days and on others I really don’t want to use it all. It’s difficult to use the Chromebook as an everyday device and give up what you are used to on a Mac/Windows PC, while you surely enjoy the dedicated cloud computing capabilities occasionally."

As part of his long term evaluation Gruener took the Cr-48 on a two day hospital stay with limited internet connectivity and concluded that the operating system is "not exactly a great experience and not everything is Google’s fault. Or perhaps it is, if Google builds a notebook that isn’t exactly ready for today’s world? I mentioned it before – Chrome OS will need massive offline capability. This should be the first priority for this OS, otherwise it will leave its users stranded much more often than will be acceptable in the foreseeable future."

Showing that Google is making progress with the operating system, Cr-48 testers received a large update in early March 2011 that included new trackpad control features, scrolling support, power improvements and a large number of bug fixes. In considering the updates Gruener stated: "It is somewhat strange how you could get excited about feature updates in Chrome OS that you have been taken for granted on Windows or Mac for as long as you can think. But then you also know that this is a new OS for a new type of application usage and your relationship to Chrome OS could be highly emotional."

**Relationship to Android**

Google's successive introduction of the popular Android and Google Chrome OS has put the company behind two open source, client-based operating systems. Microsoft CEO Steve Ballmer accused Google of not being able to make up its mind. Google has suggested that the two operating systems address different markets, mobile and personal computing, which remain distinct despite the growing convergence of the devices. Co-founder Sergey Brin suggested that the two systems "will likely converge over time". However, the two operating systems are built using entirely different processes. Chrome OS is built using Portage from Gentoo with a specific overlay called the Chromium OS portage overlay, while Android was created entirely by the developers at Android Inc and later Google, albeit based on a modified version of the Linux kernel.

**Design goals and direction**

**User interface**

Design goals for Google Chrome OS's user interface include using minimal screen space by combining applications and standard Web pages into a single tab strip, rather than separating the two. Designers are considering a reduced window management scheme that would operate only in full-screen mode. Secondary tasks would be handled with "panels": floating windows that dock to the bottom of the screen for tasks like chat and music players. Split screens are also under consideration for viewing two pieces of content side-by-side. Google Chrome OS will follow the Chrome browser's practice of
leveraging HTML5's offline modes, background processing, and notifications. Designers propose using search and pinned tabs as a way to quickly locate and access applications.

**Architecture**
In preliminary design documents for the Chromium OS open source project, Google describes a three-tier architecture: firmware, browser and window manager, and system-level software and userland services.

The firmware contributes to fast boot time by not probing for hardware, such as floppy disk drives, that are no longer common on computers, especially netbooks. The firmware also contributes to security by verifying each step in the boot process and incorporating system recovery.

System-level software includes the Linux kernel that has been patched to improve boot performance. Userland software has been trimmed to essentials, with management by Upstart, which can launch services in parallel, re-spawn crashed jobs, and defer services in the interest of faster booting.

The window manager handles user interaction with multiple client windows much like other X window managers.

**Remote application access**
In June 2010, Google software engineer Gary Kačmarčík wrote that Chrome OS will access remote applications through a technology unofficially called "Chromoting", which would resemble Microsoft's Remote Desktop Connection. The name has since been changed to "remoting," and is "probably closer to running an application via Terminal Services or by first connecting to a host machine by using RDP or VNC."

**Hardware support**
Google Chrome OS is initially intended for secondary devices like netbooks, not as a user's primary PC, and will run on hardware incorporating an x86 or ARM-based processor. While Chrome OS will support hard disk drives, Google has requested that its hardware partners use solid-state drives "for performance and reliability reasons", as well as the lower capacity requirements inherent in an operating system that accesses applications and most user data on remote servers. Google Chrome OS consumes one-sixtieth as much drive space as Windows 7.

**Integrated media player**
Google will integrate a media player into both Chrome OS and the Chrome browser, enabling users to play back MP3s, view JPEGs, and handle other multimedia files while offline.

**Printing**
Google plans to create a service called Google Cloud Print, which will help any application on any device to print on any printer. While the cloud provides virtually any connected device with information access, the task of "developing and maintaining print subsystems for every combination of hardware and operating system -- from desktops to netbooks to mobile devices -- simply isn't feasible." However, the cloud service would entail installing a piece of software, called a proxy, as part of Chrome OS. The proxy
would register the printer with the service, manage the print jobs, provide the printer driver functionality, and give status alerts for each job.

**Link handling**

One unresolved design problem related to both Chrome OS and the Chrome browser is the desired behavior for how Web applications handle specific link types. For example, if a JPEG is opened in Chrome or on a Chrome OS device, should a specific Web application be automatically opened to view it, and if so, which one? Similarly, if a user clicks on a .doc file, which website should open: Microsoft Office Live, Gview, or a previewing utility? The project director at that time, Matthew Papakipos, noted that Windows developers have faced the same fundamental problem: "Quicktime is fighting with Windows Media Player, which is fighting with Chrome". As the number of Web applications increases, the same problem arises.

**Security**

In March 2010, Google software security engineer Will Drewry discussed Chrome OS security. Drewry described Chrome OS as a "hardened" operating system featuring auto-updating and sandbox features that will reduce malware exposure. He said that Chrome OS netbooks will be shipped with Trusted Platform Module, and include both a "trusted bootpath" and a physical switch under the battery compartment that actuates a developer mode. That mode drops some specialized security functions but increases developer flexibility. Drewry also emphasized that the open source nature of the operating system will contribute greatly to its security by allowing constant developer feedback.

At a December 2010 press conference, Google claimed that Chrome OS would be the most secure consumer operating system due in part to a verified boot capability, in which the initial boot code, stored in read-only memory, checks for system compromises.

**Linux shell access**

Chrome OS includes a Bash-like shell with minimal functionality called the Chrome Shell or "crosh". In developer mode, a full-featured Bash shell can be opened via VT-2, and is also accessible via the crosh command "shell".

**Compatible hardware**

Companies working with Google to develop hardware for the operating system include Acer, Adobe, Asus, Freescale, Hewlett-Packard, Lenovo, Qualcomm, Texas Instruments, Toshiba, Intel, Samsung, and Dell.

In July 2010, Google CEO Eric Schmidt said that a Google-branded Google OS netbook was unlikely, despite Google's having previously negotiated with a couple of hardware manufacturers to produce it and despite an earlier Google-branded device, the Nexus One Android phone. "Let's see how well those partners do first. My guess is we won't need to. The PC industry is different from the phone industry. The PC industry is used to working with Microsoft, whereas the mobile industry was not used to working with software".
Hardware pricing

Schmidt has acknowledged that Chrome OS will be compatible with a smaller library of applications than conventional operating systems, like Windows, which support both Web- and client-based applications. That limitation, coupled with Chrome OS having no licensing fee, has caused speculation about the retail price of Chrome OS devices.

In April 2010, Schmidt indicated that he expected prices for Chrome OS netbooks to range from US$300 to $400, and thus be similar in cost to comparable devices that ship with closed source operating systems. He also confirmed that Google will supply the operating system for free, but it will be up to hardware manufacturers and retailers to set their own prices for the devices. When Schmidt was asked about the likelihood of phone companies bundling low cost or free netbooks with service contracts, he responded, "If a phone company chose to do that then that would be great."

Other observers had earlier forecast different pricing models. In November 2009, Glyn Moody, writing for Linux Journal, had predicted that Google's market model for the Chrome OS would be to give away the software and the netbook hardware that it will run on for free, as a means of expanding its advertising-based model. He said, "The unexpected success of netbooks over the last two years shows there is a market for this new kind of computing; giving away systems for free would take it to the next level. Then, gradually, that instant-on, secure, secondary netbook might become the one you spend most time on, and Google's ad revenues would climb even higher..."
Conclusion
The new operating system, aptly named Google Chrome OS, will be an open-source operating system initially geared toward netbooks, Google announced in a blog posting late Tuesday evening.

Google claims the new operating system, which should ship on netbooks starting in the second half of next year, will be "lightweight" and heavily Web-centric.

With Chrome OS, Google plans to follow the same formula it used with its browser: "Speed, simplicity and security are the key aspects of Google Chrome OS. We're designing the OS to be fast and lightweight, to start up and get you onto the web in a few seconds," Google stated in its announcement. "The user interface is minimal to stay out of your way, and most of the user experience takes place on the web."

Google will also make security a high priority with Chrome. The company notes it will be "going back to the basics and completely redesigning the underlying security architecture of the OS so that users don't have to deal with viruses, malware and security updates. It should just work." As you might assume, that is a pretty ambitious goal, considering every current operating system sees its fair share of security flaws and patches.

Chrome OS will run on x86-based PCs, as well as machines built around the ARM processor (such as so-called smartbooks).

So what does this mean for Android? According to Google, Chrome OS is in no way connected to Android, and that while Android was created with smartphones, netbooks, and other devices in mind, Chrome OS "is being created for people who spend most of their time on the web" and will be able to run on practically any PC that meets the minimum requirements, ranging from netbooks on the low-end to high end power desktops.
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