From Mainframes to Smartphones

A History of the International Computer Industry

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CHAPTER ELEVEN

Computer Hardware

Perhaps the biggest surprise in computer hardware after 1995 was that—contrary to what many observers predicted—the market for computer mainframes did not vanish. And although personal computers remained a key component of the computer industry in the era of the commercial Internet, in recent years they have faced strong competition from smartphones and tablets.

MAINFRAMES AND CLIENT SERVER SYSTEMS

After 1995, the migration of "mission critical" software applications, particularly ERP applications, to client-server systems continued unabated, solidifying the trend discussed in Chapter 7. This process, however, did not kill the mainframe; it rather transformed the mainframe business into one largely based on maintenance and upgrades for existing users as opposed to revenue growth.[1]

The mainframe persisted as a computer platform partly because of "legacy" effects—banks, for example, that used very old, often bespoke, mainframe-based software applications to handle customer accounts found it too costly and risky to recreate them for new computer platforms. Moreover, the rise of the commercial Internet increased the demand for mainframes from legacy users. The explosion of e-commerce fueled the need for a computing platform with high levels of availability, fault tolerance, security, high throughput, scalability, and reliability—all of which were established attributes of the mainframe.

The battle between IBM and the plug-compatible manufacturers continued after 1995. By the late 1990s, worldwide mainframe revenues were declining steadily, but the mainframe market was too important for IBM, Hitachi, and Fujitsu to abandon. IBM continued dominating the industry, while Hitachi and Fujitsu competed by attracting customers with better price-performance than IBM. In the late 1980s, Hitachi and the Dallas-based EDS formed the Hitachi Data Systems joint venture and acquired National Advanced Systems (NAS), the computer division of National Semiconductor that produced IBM-compatible mainframes. In 1997, Fujitsu acquired Amdahl Corporation, the main American manufacturer of IBM compatibles.

IBM made a "green" transition in the 1990s from its proprietary "bipolar" electronics technology to conventional CMOS, which was slower but cooler running.[2] CMOS-based machines required considerably less energy and floor space than the older mainframes. While IBM was going through the transition and its CMOS technology was evolving, Hitachi Data Systems and Amdahl-Fujitsu gained market share. By the end of the decade, however, the technology had matured, and IBM's investments in CMOS started to pay off.

In the year 2000, IBM introduced a new mainframe family, the IBM zSeries, with which it consolidated its position in the market. Throughout the first decade of the twenty-first century, IBM became even more dominant in mainframes than it had been in the 1960s and 1970s. Although the zSeries embedded important gains in price-performance relative to its predecessors, it was still a descendant of the IBM System/360 introduced in the mid-1960s. Applications written 30 or 40 years earlier for System/360 and System/370 could still run, mostly unmodified, on IBM's new mainframes.

In the new millennium, IBM generated, on average, about $3.5 billion a year in mainframe-related revenues, selling computers priced at no less than $100,000 and often at several million dollars. Although mainframe sales reportedly accounted for only about 3.5 percent of the company's revenues, hardware expenditures were often accompanied by complementary and substantial expenditures in software and maintenance contracts. According to some estimates, as much as 40 percent of the company's profits in the 2000s were mainframe related.[3]

Other hardware manufacturers that had risen rapidly on the computer scene of the 1980s and early 1990s did not fare as well as IBM after the mid-1990s. DEC, for example, which in its glory days of the late 1980s had become the second-largest computer company (after IBM), saw its

VAX line of midrange computers attacked on a number of fronts and ended up being acquired by Compaq in 1998; the deal was worth $9.6 billion, making it the largest transaction of its kind in the history of the computer industry up to that point.[4] For Compaq, the transaction made sense as a quick way to consolidate its position in enterprise computing—DEC was an attractive target for its strong computer server business.

Compaq, however, could not manage to remain independent for long; in 2002, it was acquired by Hewlett-Packard in a $25 billion operation.[5] The HP-Compaq merger was intended to create a company strong enough to compete both with Sun Microsystems and IBM in the server computer market and with major vendors in the personal computer market. The operation created a computer company almost as large as IBM.

The Compaq acquisition gave HP important computer assets in the server and personal computer markets but was less effective at enhancing HP's role in computer services. Whatever HP was lacking in this latter market it obtained through its $13.9 billion acquisition of EDS in 2008, a deal that more than doubled HP's revenues in the computer-services segment.[6]

The other superstar computer company of the 1980s and 1990s, Sun Microsystems, survived as an independent entity for a longer time by specializing, among other things, in workstations and servers that ran the company's flavor of the UNIX operating system. Its performance in the first decade of the twenty-first century was inconsistent, however, and it ended up being acquired by Oracle in 2010 in a $7.4 billion deal.[7]

The Oracle acquisition of Sun Microsystems was unusual in that it involved a company focused on software and services buying another firm that had strong computer hardware assets. One possible interpretation of the transaction is that, in the context of an industry operating under the shadow of a strongly diversified mammoth such as IBM, some companies decided to become diversified giants themselves in order to compete. After all, from its origins, the data-processing industry aimed at offering a "total solution" to clients involving hardware, software, and services.

PERSONAL COMPUTERS

The rise of the commercial Internet in the second half of the 1990s enhanced sales of personal computers. Some sort of "information appliance" was needed to gain access to the Internet, and the personal computer was, until recently, the king and queen of all such appliances.

In the years immediately after 1995, personal computer shipments

grew at a steady rate, propelled by the rise of the Internet. The proportion of adults using the Internet in the United States, for example, grew very rapidly, from 14 percent to 50 percent, between 1995 and 2000. The proportion kept on rising thereafter, but at a slower rate—it had reached 74 percent at the end of 2009 and 87 percent by early 2014.[8] Worldwide, personal computer shipments grew from 80.6 million units in 1997 to 134.7 million units in 2000. Production stalled slightly during the dot-com bust of 2000–2001 but continued rising thereafter.

Competing personal computer vendors established different business models for PC assembly, distribution, and marketing. The "retail assemblers" were the small local suppliers that thrived on the basis of local-market knowledge, accessibility (typically being located in a retail park), customer service, and low production overhead. Until 2005 or so, they held a 25 percent share of the market in the United States and an even larger share in other countries.[9] They did not have the economies of scale of the larger producers, but their proximity to customers provided a profitable niche.

The "standard mass assemblers"—IBM, Compaq, HP, Siemens, Sony, NEC, Fujitsu, and Samsung, to name some of the largest—functioned on a quarterly plan: they forecast how many personal computers in different categories the market would be able to absorb, and then they built the PCs, or often subcontracted their assembly, in light of that forecast. In the late 1990s and early 2000s, much of this subcontracting involved Taiwanese firms. In fiscal year 2000, for example, Compaq had total sales of $35.6 billion and imported $9.5 billion worth of components from Taiwan alone. In the first decade of the 21st century, subcontracting and computer assembly moved toward China and other regions on the basis of cost differentials (discussed further in Chapter 12).

The "build-to-order" firms, such as Dell and Gateway, took customer orders first and then built personal computers on the basis of the orders received. This approach dealt effectively with some of the key problems the industry faced. One of them was that components lost value at an extremely fast pace, some as quickly as 1 percent per week. Since companies such as Dell and Gateway did not start building computers until the order was received, they minimized excess inventory issues. Furthermore, the build-to-order model eliminated much of the risk involved in projecting consumer demand. By contrast, for the standard mass assemblers such as Compaq and IBM, failed projections often led to oversupply and extreme discounting, or to undersupply and missed opportunities.

A Chinese company appeared for the first time among the top five when IBM sold its personal computer business to Lenovo in the mid-2000s. Acer, a Taiwanese company whose origins were briefly described in Chapter 9, appeared for the first time among the top five in 2004. In recent years, Dell, HP, Acer, Lenovo, and Toshiba have vied for the top spots, and the share of the rest has shrunk.

The ups and downs of the world's top personal computer makers convey the relative success of different competitive strategies. They also hide a more important fact: in recent years, new appliances—smartphones and tablets—have started eroding the role of the personal computer as the dominant computing device.

SMARTPHONES: THE FIRST ENTRANTS

The mobile phone (often termed a "cell phone" in the United States) emerged as a consumer item in the early 1990s, in effect riding on the technology and infrastructure for mobile telephony that had been developed earlier to satisfy the corporate communications market and elite customers.[10] The second half of the 1990s saw a wave of new single-function consumer devices, such as media players, digital cameras, and GPS systems, and infrastructure to support them. For a small increment to manufacturing cost, it became feasible to incorporate audio players and digital cameras into a mobile phone, which thus became a "feature phone"—an integrated bundle of special-purpose devices with capabilities that were frozen at the time of manufacture.

The term "smartphone" came into use in 1997 and represented a new way of thinking about mobile phones. Smartphones were no longer single-purpose or multipurpose devices, but rather universal handheld computers that incorporated a telephone. A key feature of smartphones was the ability to run software programs, later called "apps," that enabled them to perform tasks that had not been envisaged when the phone was manufactured. Smartphones are, at their core, classical universal computers.

Smartphones were built on the technology of handheld computers, often called personal digital assistants (PDAs), developed within the computer industry. All of the early smartphones had at their core software operating systems devised for PDAs. The main ones in the pre-2007 period were Palm OS, Windows CE (later called Windows Mobile), Symbian, and BlackBerry OS.

Palm Computing was founded in 1992 by Jeff Hawkins, the creator of one of the first handheld computers, the GRiDPad. In 1996, after being

acquired by U.S. Robotics, Palm introduced the PalmPilot 1000, a PDA that incorporated handwriting recognition. Designed as an electronic Filofax-type organizer rather than a full-fledged computer, the PalmPilot 1000 sold more than a million units in the first 18 months after introduction.[11] The operating system that controlled the PalmPilot PDA, the Palm OS, was first used in a smartphone in 2001.

The success of the PalmPilot 1000 generated a flurry of entry into the PDA market. Microsoft had started working on an operating system for mobile computing devices in late 1994.[12] By September 1996 it had entered into agreements with six hardware partners—Casio, Compaq, HP, LG Electronics (for Hitachi), NEC, and Philips—to bring to market PDA-like devices running on the Windows CE operating system. These early Windows-based handheld computers were not particularly successful. By late 1997, Palm had about two-thirds of the market for handheld computing devices, and Windows came much further behind. Smartphones based on Windows CE were not introduced until 2002.

Symbian has its roots in an operating system named Epoc developed by Psion, a British computer company.[13] Psion was founded in 1980 by David Potter, an academic physicist, and in its early years became a leader in software for microcomputers. In 1994, Psion introduced a small handheld computer, the Series 3, which was a hit in the British market. After the Series 3 took off, Psion engineers started designing an operating system, called Epoc, to serve as the foundation for the long-term successor to the Series 3. While exploring the possibility of licensing its as-yet-unreleased operating system, Psion established a relationship with Nokia, the Finnish conglomerate, which was about to introduce the Communicator 9000, a combined mobile phone and PDA. Negotiations between the companies led to an agreement that would allow Nokia to use the Epoc operating system on its future line of Communicator devices.

Symbian, a spin-off of Psion, was founded in June 1998; it owned the Epoc operating system and was co-owned by some of the key players in the mobile phone industry (Nokia, Ericsson, and Motorola). The Symbian operating system was used on a mobile phone for the first time in 2001.

The story of the BlackBerry dates back to 1984, when two engineering students, Mike Lazaridis and Douglas Fregin, founded Research in Motion (RIM) as an IT consulting business in Waterloo, Ontario. From the beginning, the firm specialized in wireless data transmission.[14] In 1996, RIM introduced the first two-way messaging device, the so-called Inter@ctive Pager; three years later, it came out with the first product in a line that would bring the company international recognition: the

BlackBerry, a device that allowed business executives to access their corporate e-mail wirelessly from anywhere at any time. RIM's first smartphone, the BlackBerry 5810, reached the market in 2002.

SMARTPHONES: APPLE'S IPHONE

The smartphone market changed radically with the arrival of Apple's iPhone in June 2007. Apple's management had started exploring the development of an Apple phone in 2002, soon after the introduction of the iPod.[15]

The iPod was a portable media player that Apple unveiled in October 2001. Early that year, Apple had also introduced iTunes, an application used to download, organize, and play digital audio. The iTunes Store opened for business in April 2003. One of the key problems consumers faced in the early 2000s, and especially after the introduction of the iPod, was mobile device proliferation—they were carrying around too many gadgets, including a PDA, a phone, a media player, and sometimes a digital camera. Around this time, some attractive "convergent" devices, such as the Palm Treo 600, started appearing on the market.

By 2004, the iPod business, which already accounted for 16 percent of Apple's revenues, looked promising but also vulnerable due to the increased sophistication of mobile phones. Furthermore, online music stores rivaling Apple's iTunes were proliferating. Apple responded with a "music phone," the ROKR, jointly developed with Motorola and introduced in 2005. The ROKR—which had an unfriendly interface, could hold no more than 100 songs, and had to be synced with a personal computer to complete a purchase from the iTunes store—sold well below expectations despite an expensive marketing campaign.

As the ROKR episode was unfolding, Apple established a business relationship with Cingular, the wireless carrier. Apple and Cingular—which was acquired by AT&T in December 2006—held protracted negotiations that led to a deal centered on the introduction of an Apple phone. Apple's iPhone, developed in an atmosphere of complete secrecy during 2005–2006, was announced by Steve Jobs in January 2007.

Jobs presented the iPhone as a "revolutionary mobile phone" that combined the capabilities of a phone, an iPod, and an "Internet communicator."[16] The entire front surface of the iPhone was a touchscreen, and all of its functions were activated by touch. It ran the Mac OS X operating system (later rebranded iOS when used on the iPhone), offered a radically new and improved Internet access capability, and was able to wirelessly download music and movies from the iTunes

store.

In the second quarter of 2007, when the iPhone became available commercially, Symbian was the undisputed leader in the world smartphone market with a share of almost 66 percent of all units sold. The iPhone market share grew quickly, from less than 1 percent when it was introduced to over 16 percent in late 2009. The rise of the iPhone was accompanied by a steep decline in the market shares of both Symbian and Windows CE; the share of the Blackberry OS kept on growing through late 2009 because the Blackberry phone was less of a consumer item and benefited from the inertia of being embedded in many organizations.

SMARTPHONES: GOOGLE'S ANDROID

By late 2008, the iPhone was the brightest star in the smartphone universe. Its ascent, however, did not remain uncontested for long. That September, T-Mobile released the first smartphone running on Android, a mobile operating system owned by Google.

The history of Google's Android goes back to Andy Rubin, a computer and electronics hobbyist who early in his career had worked for Apple.[17] In the late 1990s, Rubin and a group of engineer friends founded a start-up in Palo Alto, California, named Danger Inc., which in the early 2000s developed the Sidekick, one of the first smartphones to effectively combine web access, e-mail, instant messaging, and other applications. In 2002, Rubin met Page and Brin, the Google founders, who were pleasantly surprised to find that Google, which had a tiny share of the search market at the time, was the default search engine on the Sidekick.

The Sidekick developed a fan base among computer-savvy teenagers but never became a contender in the broader smartphone market. Rubin left Danger Inc. in 2004 and launched a new startup, Android, whose goal was to design an open-source mobile platform available to all developers and handset makers for free. The company would generate revenues by selling support services for the system.

In 2005 Rubin approached Page to obtain Google's endorsement for Android. Rather than just endorsing the start-up Google acquired it in July 2005 for an estimated $50 million. This unleashed speculation in the technology world about the potential implications of Google's turning into a smartphone vendor.

At the time it acquired Android, Google was reportedly concerned about two facts: first, web surfing had started to migrate from personal computers to mobile phones, and second, the Internet capabilities of existing feature phones were too primitive, because they were originally

designed for low-bandwidth devices. Consumers' migration toward the mobile web could potentially undermine the foundations of Google's success because mobile phones were not particularly effective platforms for Google's services and ads.

Android's acquisition by Google did not turn it into a smartphone vendor per se. Unlike Apple, which sold the iPhone as an integrated and proprietary bundle of hardware and software, Google chose to follow a strategy not unlike that which Microsoft had employed in the 1980s in its relationships with PC makers—Google developed an operating system and licensed it to any and all handset makers. The key difference between Google's Android and Microsoft's operating systems was that Android was open-source and cost the handset manufacturers nothing. Rather than generating revenues from licensing, as Microsoft had done with its operating systems starting in the early 1980s, Google would make money from smartphone advertising.

In November 2007, shortly after the iPhone had reached the market, a group of technology companies that included Google, T-Mobile, HTC, Qualcomm, and Motorola announced the formation of the Open Handset Alliance for the development of the Android operating system, somewhat in the model of the original Symbian consortium. The first successful Android smartphone was Motorola's DROID, which reached the market in October 2009.

The market share of Android in the world smartphone market grew quickly. By early 2011, Android had become the leading operating system in the market with a 36 percent share of all units sold, followed by Symbian (27 percent), Apple's iOS (17 percent), the BlackBerry OS (13 percent), and Windows Mobile (just under 4 percent).

SMARTPHONES: APP ECOSYSTEMS

The battle among smartphone vendors centered on attracting app developers to each platform. In March 2008, Apple unveiled a software development kit for the iPhone, and the venture-capital firm Kleiner Perkins Caufield & Byers set up the iFund, a $100 million fund to invest in applications for Apple's smartphone. Google responded with the $10 million Android Developer Challenge.[18] Although the Challenge could not rival the iFund in the magnitude of its monetary rewards, it attracted app developers in search of exposure.

In July 2008, Apple launched the App Store, which featured applications for both the iPhone and the iPod touch (a cut-down version of the iPhone, without communication facilities, sold as a media

player).Two months after launch, over 3,000 apps were available on the App Store and users the world over had already made more than 100 million app downloads.

Google's own app store, Android Market, was announced in August 2008. By the following year, it had become clear that third-party applications would drive the growth of the smartphone business, and all the major smartphone players—including BlackBerry and Microsoft—were either seriously considering or already involved in the launch of an app store to compete with Apple's.

By September 2012, about 700,000 apps were available on Apple's App Store and users had made roughly 35 billion app downloads. But Android Market (renamed Google Play in March 2012) was catching up —it had 675,000 apps available and 25 billion app downloads.

SMARTPHONES: RECENT DEVELOPMENTS

In recent years, the rise of iOS and Android and the corresponding decline of the incumbents (Symbian and the BlackBerry OS) brought about important realignments in the industry. After Apple introduced an improved smartphone, the iPhone 3G, in mid-2008, Nokia, which owned 48 percent of Symbian, announced that it would buy the remaining 52 percent from the other stakeholders and would then set up the Symbian Foundation to "unify" and "open source" the Symbian operating system for smartphones.[19]

The Symbian Foundation—whose founding members included Nokia, Sony Ericsson, Motorola, NTT DOCOMO, AT&T, LG Electronics, Samsung Electronics, Texas Instruments STMicroelectronics, and Vodafone—was an attempt by some of the key industry players to stop the decline of what had been the leading mobile operating system in the world. The attempt was unsuccessful and by late 2010, the Foundation had become purely a licensing body.

Although Nokia continued supporting the development of the Symbian operating system in theory, in practice it searched for alternatives to remain competitive in the changing smartphone market. In February 2011, Nokia announced a mobile phone partnership with Microsoft. The agreement specified that Nokia would use Microsoft's Windows 7 as the primary operating system on its mobile phones and announced the partners' intent to establish a third ecosystem that encompassed app developers and network operators. Nokia chose to form an alliance with Microsoft, as opposed to adopting Android as its mobile operating system, because it feared it would be difficult to differentiate its

brand in the Android ecosystem. It chose to be the key handset maker on the Windows platform rather than being one among many on the Android platform, even though the installed base of Microsoft's mobile platform did not compare with that of Google's.

RIM, the other incumbent in decline, tried a different strategy to stay competitive. It developed a new operating system, BlackBerry 10, and unveiled it in early 2013 at the same time that it renamed the company itself BlackBerry.

Figure 11.1 tracks worldwide market shares for mobile operating systems between 2007 and 2012. Although Symbian continued to grow up to 2010, its share of the rapidly growing market was in decline. By 2012, it had been completely eclipsed by iOS and Android.

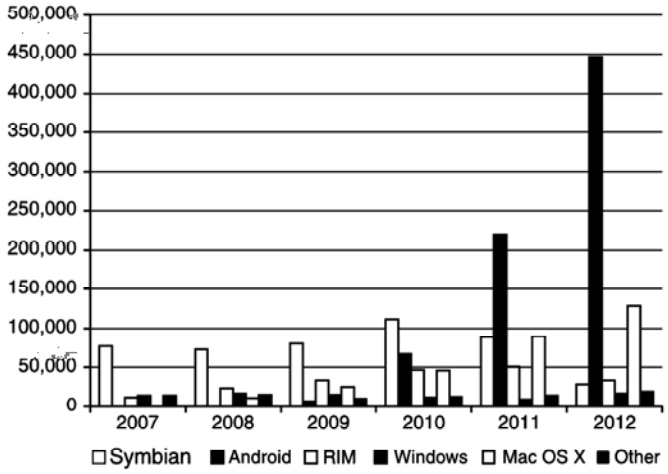

Figure 11.1. Worldwide sales of smartphones by operating system, 2007–2012. Units in thousands.

Source: M. Campbell-Kelly, D. Garcia-Swartz, R. Lam, and Y. Yang, "Economic and Business Perspectives on Smartphones as Multi-Sided Platforms," *Telecommunications Policy* (2015, forthcoming) and the sources cited therein.

TABLET COMPUTERS

Current-generation tablet computers are portable computing devices that evolved from the user experience and technologies of smartphones, equipped with larger screens and stripped of their telephony functions. Although the introduction of Apple's iPad in April 2010 changed the tablet market in a radical way, the concept of the tablet computer was developed much earlier. In the 1970s and 1980s, there were several attempts by Xerox, Palm, Microsoft, Apple and others to develop a

handheld computer in tablet form. These efforts were unsuccessful commercially, but the technologies developed subsequently evolved into smartphones and then tablet computers.[20]

The earliest design for a tablet-style computer came from a Xerox's PARC research group led by the computer scientist Alan Kay, which set out to develop a portable computing device called the Dynabook in the early 1970s. Chuck Thacker and Butler Lampson, the two PARC engineers who worked with Kay on the project, built the Alto desktop computer, the closest they were able to get to the Dynabook concept with the technology then available. Xerox subsequently launched desktop computer products (the Star and model 810) based on the Alto in the early 1980s, but they were unsuccessful due to their high price, as discussed in Chapter 7. Apple later adopted Xerox PARC's ideas for its Macintosh computer.

In 1987, Apple engineer Steve Sakoman, who had helped lead the teams responsible for the development of various Macintosh models, started working on an Apple tablet computer, the Newton.[21] The first version of the Newton, called MessagePad, did not reach the market until mid-1993. Handwriting recognition, which was supposed to be one of its key features, worked imperfectly at best. Between 1993 and 1997, Apple introduced eight different Newton models, mostly under the MessagePad name, with modest results. By early 1998, when the project was discontinued, the firm had reportedly invested half a billion dollars into its development and marketing, achieving an installed base of at most 300,000 devices at a time when the installed base of Windows CE handheld computers was about 500,000.

The same two engineers who built the Alto in the 1970s, Thacker and Lampson, headed a design team at Microsoft that, in the late 1990s and early 2000s, developed the company's Tablet PC device. Although the prototype looked promising, Microsoft's Tablet PC (and those made by other manufacturers) remained a niche product. By 2005, Tablet PCs accounted for 1.5 percent of portable PCs sold worldwide. Among the main reasons for the early tablet computers' limited success were their stylus-based, unfriendly interface (compared with the later touch screen) and the lack of tablet-specific software applications.

Just as there was a "before" and "after" the iPhone in the market for smartphones, there was a "before" and "after" the iPad in the market for tablet computers. Introduced in January 2010, the iPad was, according to the Apple news release, a "revolutionary device" designed for browsing the web, reading and sending e-mail, viewing pictures, watching videos,

listening to music, playing games, and reading e-books.[22] Out of 16 million tablet computers shipped worldwide in 2010, 15 million were from Apple.[23]

Competition in the tablet market intensified in 2011, coming mainly from Android-based devices. Apple's share of the table market declined to almost 67 percent in 2011, and Android's share grew to almost 29 percent, with smaller players, such as BlackBerry, accounting for the rest. As this book was going to press, the market for tablet computers remained strongly contested, with Microsoft having introduced a hardware product, the Surface, in June 2012, as well as adding interface improvements to its Windows 8 operating system that make it suitable for tablet devices.

THE IMPACT OF THE COMMERCIAL INTERNET: TAKING STOCK

The period from 1995 to 2010 (and beyond) has been one of standards diversity. System/360 and its compatible successors still reign supreme in the world of mainframes, whereas the IBM PC standard still dominates the personal computer segment. Computers of various kinds have been connected with one another through a network of networks, the Internet, built around open standards. The arrival of the "mobile Internet" has brought to the forefront new standard battles, particularly between Apple's iOS and Google's Android.

Although the arrival of the commercial Internet brought about the demise neither of the mainframe nor of the personal computer, the rise of the mobile Internet in recent years is having a major impact on the computer scene. In early April 2013, news agencies reported that worldwide personal computer shipments in the first quarter of the year had declined by more than 10 percent relative to the same period in 2012, the greatest drop on record.[24] Analysts declared that a tipping point had been reached and that mobile computing was in the ascendant.

Whether a new era of computing—the "mobile Internet" computing cycle—has begun or not is debatable, but new trends in computing are certainly evident. Users are flocking to smaller and lighter computing devices that allow them to access the Internet from anywhere at any time; the mouse-driven and touch-pad user interfaces are giving way to the touchscreen; and "apps" created for smartphones and tablets increasingly compete with the web as channels for accessing Internet content.[25]

Mobile devices are both complements and substitutes for desktops and notebooks. Many computer users have acquired smartphones and tablets in addition to, and not as a replacement for, the devices they already own.

More generally, smartphones and tablets have tended to replace desktops and notebooks for content consumption—listening to music, viewing pictures, watching videos, playing games, and general Internet browsing—while traditional personal computers have held their own in content creation—creating and editing spreadsheets and documents, among other things. But since, according to some surveys, 75 percent of computer usage is content consumption and sharing, rather than content creation, the rise of smartphones and tablets will likely cannibalize personal computer usage, and has already started to do so.