The PC is Dead—Long Live the PC: Making Computing More Personal

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Abstract. It has been more than 30 years since Steve Wozniak and Steve Jobs built the first Apple I computer in Job's garage and since IBM introduced the Model 5150 personal computer. In that time, the PC has become an integral part of our lives; more than 80% of all households own at least one, and rare is the business or workplace that can function without one.

Yet today, the dominance of the PC as our primary computing device is being threatened by new, emerging platforms like tablet computers, cell phones and ultrabook platforms. The rapid success of these new models, such as Apple's iPad, is leading many to surmise that the end of the PC era has arrived and that the PC is dead. But is the PC really dead, or are advances in technology simply allowing the PC to morph into something new and even more exciting?

Advances in Semiconductor Process Technology

In part, the tremendous advances brought about by the semiconductor industry have not only fueled the growth of personal computers, but also enabled these impressive new computing platforms. To put some scale on the advances of this industry, consider the clock rates and memory densities put forth by the leading manufacturers in the processor and memory arenas. When the IBM PC was introduced, the CPU ran at a whopping 4.77 MHz. Today's CPUs, running at 3.5 GHz with hyper-threaded, multicore CPUs on one chip, provide an improvement of almost 8,000 times. Similarly, consider that at the introduction of the Apple I computer, a state-of-the-art memory device could store 16K bits of information. Today's state-of-the-art NAND Flash chips store up to 128Gb of information on a single piece of silicon—an 8-million-fold increase.

Along with semiconductor speed and density improvements, we have seen a corresponding improvement in the power required to support the chips' circuits. There is also a tradeoff that can be made between performance and power so that if one is willing to accept a reduced level of performance, they can realize tremendous savings in power. For example, the same advances that can deliver a 3.5 GHz quad-core CPU that consumes 65W of power can also deliver a 1.5 GHz dual-core CPU that sips a miserly 5W of power.

Device-level Advancements

While Dynamic Random Access Memory (DRAM) devices have benefitted from the advances in semiconductor processes, DRAM power and performance are increasingly coming under pressure as areas that need major improvements. Fortunately, the memory industry has not been silent; it has delivered a stunning new technology into the hands of system designers in the form of the Hybrid Memory Cube (HMC). HMC makes a dramatic change to the architecture of the CPU and memory interface and provides a 15-fold increase in data bandwidth while lowering power consumption by 70%.

The HMC relies on a 3-D stack of semiconductor chips interconnected with a new technology called Through-silicon Vias (TSVs). The short length of these TSV interconnects gets much of the credit for reducing the energy-sapping inductance and capacitance of standard 2-D interconnects. However, equal credit must be given to new device architecture and I/O. The device architecture ensures an efficient use of the memory cells that get fetched by the system using the HMC device. In addition, unlike any previous memory device, the HMC uses high-speed serializer/deserializer channels for its I/O.

Perhaps the biggest advancement in memory over the past 20 years has been the development of NAND Flash memory. NAND Flash, which gets its name from the logical organization of its memory cells (in a "Not-AND" formation), offers two major advantages over DRAM: cost and power.

Although memory processes are generally the most cost-effective semiconductor processes on the planet, NAND Flash is the king of cost effectiveness. This is due to the advanced process technology employed to build these miniature marvels and the relative simplicity of the process compared to other semiconductor processes. Today's most advanced NAND devices are now in production with geometries below 20nm (1nm = 1/1-billionth of a meter) and pack more than 128Gb (1Gb = 1 billion bits = 128 billion bytes) of storage on a single semiconductor die. Making NAND even more cost effective, consider the cell size of a NAND cell is about two-thirds that of a DRAM cell and one-tenth that of a Static Random Access Memory cell (like that used in a CPU cache), and each NAND cell stores two or three bits of digital data.

The power advantage of NAND Flash stems from the fact NAND Flash is nonvolatile, meaning that the NAND memory cells retain their value even when power is removed from the chip. This nonvolatility has enabled NAND Flash to become the predominant form of storage for cell phones and tablets. NAND Flash is also making tremendous inroads into computing in the form of Solid State Drives (SSDs) for both notebook and server applications. The advantage of having no moving parts allows SSDs to achieve extreme levels of reliability, performance, and low power consumption in these applications.

The New Computing Paradigm

The advances in CPUs and memory have enabled a wide variety of innovative and successful computing platforms, including tablets and smartphones. In the U.S. alone, smartphones accounted for an estimated six out of every 10 mobile phones sold in 2011 [1]. The successful iPad, its competitors and e-readers accounted for an estimated $64 million to $66 million in tablet computer sales in 2011 [2]. At the 2012 Consumer Electronics Show, the buzz about computers centered on a new class of mobile computing platform—the ultrabook. Ultrabooks are a new class of notebook computers that have the advantage of being thin and light while also offering long battery life. Smartphones, tablets, and ultrabooks represent a true paradigm shift in computing, from traditional personal computers to mobile and cloud-based solutions. Yet this shift is really making computing more personal.

Much of computing today requires connectivity. Whether it is e-mail, surfing the web, shopping, watching video, or gaming, the network is a required component of the computing experience. The growth in mobile network traffic has been phenomenal. Mobile network traffic alone in 2010 was more than three times the entire global Internet traffic in 2000 (237 petabytes per month versus 75 petabytes per month [3]). The increase in mobile traffic volume is also scaling in speed with the average smartphone network connection speed climbing from 625 kb/s in 2009 to 1040 kb/s in 2010 [3]. This increase in mobile network bandwidth and the overall increase of mobile network availability are two of the forces behind the enablement of the smartphone and tablet computer. The other significant force has become known as "the cloud."

Cloud Computing

If you happen to be fortunate enough to own an Apple iPhone 4S, you have probably used Siri, the voice-activated personal digital assistant. For Siri to work, many components are required. The most obvious component is the voice recognition used to interact with Siri. You might think this voice recognition is a function of the iPhone, but in reality very little processing is actually performed by the handset. Instead, the phone uses its connection to the Internet to send highly compressed code to servers that are set up to process the encoded data. These servers pick out the context and meaning of what was spoken to the phone. Once the context of the spoken commands is determined, the cloud is again used to provide the data being requested, in much the same way that you might perform an Internet search. If you asked Siri a question about the weather, the Siri servers would turn this into a web service request from a weather site accessing the site's data to provide your answer, which it would then deliver in text and speech.

There are countless other examples that might be given, but the important effect of the cloud is that it can provide both computing resources and data storage resources to computing devices. It means your personal computing device does not need the amount of processing power or storage that it would need if it were trying to perform all of its tasks locally. A cell phone can use the cloud to access data it does not have room to store in its limited amount of local memory; and a tablet computer can tap into cloud-based services to augment the compute power of its lower-powered processing chip.

The Effect of Usage Models

Human interface factors of non-PC computing platforms often dictate their usage. For the personal viewing of a YouTube video, the large screen of a tablet computer may be just about ideal. Tablets are also popular for watching movies on a plane, writing e-mail, surfing the web and playing games. The screen size is excellent for one-on-one viewing or sharing with another. On the other hand, the small screen size of most cell phones limits viewing to one user, and most web content is not optimized for the limited viewing area.

Screen size is not the only factor that determines usage. For authoring content, it is hard to beat the keyboard of a personal computer. The touch screen keyboards of tablets and smartphones are great for short e-mails and brief notes, but lack the tactile feedback needed for extended typing. Even simple functions such as cut and paste are made difficult by touch-based user interfaces.

Perhaps keyboard input will give way to speech input, allowing tablets to fully take the place of PCs, but it is hard to imagine an office full of people talking to their tablets in a productive manner. At the 2012 Consumer Electronics Show, one Chinese company was demonstrating a "thought-controlled" computer interface. If only it worked reliably!

Some have said the differentiator between PCs and smartphones/tablets is that the latter are content consumption devices, while PCs are content creation devices. This is true in some cases, but dead wrong in one very big case: pictures and video. All smartphones and most tablet computers sold today have at least one camera sensor built in. Mobile video consumption already accounts for more than 52% of mobile video traffic. In fact, in October 2011 alone, 201.4 billion online videos were watched around the world, reaching 1.2 billion unique viewers [4]. But where is all this video data coming from? Increasingly, smartphones and tablet computers are capturing video. At the end of 2011, users were uploading more than 60 hours of content to YouTube every minute—a number that is only expected to grow.

Secure Computing

One major concern for mobile devices of all types is data security. Mobile devices carry an increased risk of data loss, a risk that will restrict access to certain data by fixed (PC) computing resources. Technologies are entering the mobile space to help mitigate this concern. Micron's own C400 SED SSD is a solid state drive that incorporates 256-bit hardware encryption yet delivers the same performance, power advantages, and reliability of Micron's non- encrypted drives. Unlike software-based encryption, which is vulnerable to attack through the memory, operating system, and BIOS, the C400 SED's hardware-based encryption is performed in the SSD hardware, requiring user authentication to be performed by the drive before it will unlock, independent of the operating system. While this encryption technology is only shipping in personal computer drives today, it will find its way into tomorrow's mobile computing solutions.

One Size Does Not Fit All

The personal computer has been the driver and beneficiary of tremendous advances in semiconductor processes and products. Probably more than any other technology, the PC is responsible for huge gains in productivity in most developed parts of the world, and it will continue to be the vehicle for productivity advances in emerging economies around the globe. At the same time, the ease of use and ubiquity of mobile networks will make smartphone and tablet computing attractive for many users.

Is the PC dead? Hardly! But the definition of "personal computer" must not be too narrow. Today's smartphone or tablet is a much more personal computing device than the traditional PC. These platforms possess the processing and storage capability of the desktop personal computer of only a few years ago, yet we carry them in our pocket daily, and we talk to them and touch them.

The overall market for computing platforms has taken a leap as these new mobile computing platforms have gained popularity. While the growth of PC computing has stopped, the smartphone and tablet have combined to fuel continued growth in the semiconductor market for CPUs and memory—key components for all computing platforms. Innovative computing platforms will drive new innovations around the supporting circuitry for these platforms, fueling continued development of CPU, DRAM, and NAND Flash technologies.

Conclusion

Computing solutions, both mobile and fixed, are placing increased demands on cloud computing and storage infrastructure—demands for better access to ever-increasing amounts of data and unprecedented levels of server computing resources and storage resources. Increased use of multicore CPUs, software virtualization, high-speed DRAM, and SSDs are the key building blocks for tomorrow's cloud computing and storage environment.

So is the PC dead? Far from it! But the PC is changing. Our smartphones and tablets have more computing power and storage than our PCs did only a few years ago, enabling these platforms to be much more personal forms of computing than the PCs we have been used to. For many users (and many applications), smartphones and tablets will be the preferred computing device. For others, the PC will be irreplaceable until user interface technology makes the leap forward to enable content creation on new computing models—models that may be far different from even smartphones or tablets.

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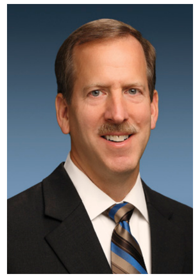

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