From the Editor in Chief

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When Cell Phones Become Computers

Roy Want

One day your primary computer, the device you use for the majority of your work, will be mobile, easily fit in your pocket, and be completely integrated with your mobile phone. This is a vision held by a growing number of people in the computer industry, and as each new generation of mobile phone is released into the market, a more convincing case can be made.

What are the driving forces behind this trend? For any mobile device there are two major constraints: battery lifetime—the ability to use the device for a reasonable period of time between recharging (one day usually being the minimum); and size and weight—the device must fit in a pocket or purse. For more than 10 years, the industry has been able to satisfy these conditions for a communication device—hence the development of the mobile phone and its explosive market success. In the last year, the industry estimates it shipped more than 1.2 billion cell phones—a colossal market size by any standard. When you consider that cell phone customers represent a subscriber market of 3.3 billion, it's a staggering number— approximately half the earth's population.

It is, however, the case that the majority of these devices are basic cell phones, and aren't good for much more than making voice calls, and a simple phone book function. Every cell phone can be architecturally divided into two basic components: the communication processor, and the applications processor. And to reduce cost, the engineering trend is to build everything into the same piece of silicon, often called system-on-chip (SoC). In a simple phone the communications processor is the center of the design effort, with the applications processor little more than a low-end microcontroller. The fundamental difference between a cell phone and a smart phone is that the application processor becomes a computationally powerful computer in its own right, one that can run general purpose applications. It is because of this trend in smart phone design that the PDA market has been in decline; the functionality has simply been absorbed by high-end phones, and it no longer makes sense to buy a PDA without a complementary cellular communication capability.

2007 was the crossover year for smart phones exceeding laptop computer sales; a significant milestone for the industry.

You might be wondering how big the smart phone market is relative to the cell phone market. In 2007, it was estimated to be a little less than 10 percent at 116 million units, growing to 181 million units in 2008, or 14 percent (see Figure 1). Therefore, smart phones have a way to go before they embody the majority of cellular sales, currently about 1.2 billion. If you consider that in 2006 the laptop computer market was roughly 82 million units, and grew to 108 million in 2007, it can be seen that 2007 was the crossover year smart phones exceeding laptop computer sales; a significant milestone for the industry. One of the factors limiting for smart phone sales is their cost, as much as 3 to 5 times the cost of a low-end cell phone, but as with the trends in all mass-market electronic goods, the cost is falling. Also, most people who buy low-end phones tend to replace them with more full-featured versions, and therefore drive the market forward. Looking at the forecast in Figure 1, smart phones might account for between 25 to 30 percent of the total cell phone market by 2013. Given the recent global

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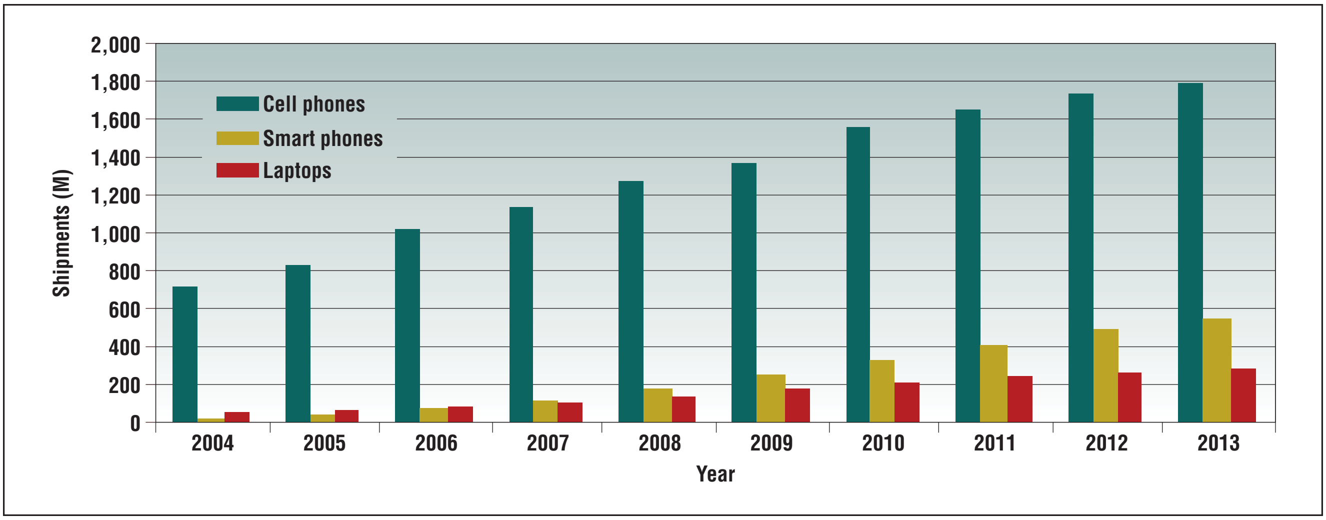

Figure 1. Cell phone, smart phone, and laptop shipments worldwide (M) 2004-2008, forecast 2008-2013. Source: Intel Library

economic woes, this large percentage might be wishful thinking, but it does indicate there is a trend in this direction.

I'm sure some of our readers are considering this article and thinking that these smart phones have lots of nice features, but don't represent what most people consider full featured computers. Based on today's models I would have to agree, so why do I think this is going to change? Before I answer this question, in the interest of full disclosure, I would like to remind you that I work for Intel, and you might consider my viewpoint somewhat biased. To try and keep things balanced I will stick to facts as much as possible, and you can decide whether my conclusions are valid.

In April 2008 at the Intel Developer Forum (IDF) in Shanghai, China, Intel announced a new family of low-power mobile processors called Atom. The first generation of these processors (Menlow) was implemented with 47 million transistors, the smallest number of transistors used in a fully compatible x86 architecture since the Pentium 4 in 2001, containing roughly 42 million transistors. By comparison, a modern quad-core processor (Penryn) aimed at the PC server market requires 820 million transistors. Menlow was implemented using a 45nm process, the most advanced in full production, and employing a 1.85GHz clock, it is the highest performing processor with an average power in the 1 to 2 Watt range. Later, at the Fall 2008 IDF, Intel announced the next generation of the Atom family, called Moorestown, which is expected to be available in the latter half of 2009 with considerably lower power dissipation.

While these processors are targeted at small handheld computers, such as Mobile Internet Devices (MIDs), Ultra Mobile PCs (UMPCs), and NetBooks, they still consume too much power to be used as the core of a smart phone. However, given these trends, you can see where the engineering goals are driving the next-generation processor design. Further, these processors are able to execute full-featured operating systems such as Linux and Windows, and the legacy x86 binaries that already run on our PCs. As a result, developers can design software for desktops, debug it, and have it run on mobile platforms without recompiling the main code base, Something that could revolutionize software development for the phone market.

Perhaps I've convinced some of you there is good reason to believe that x86 processors are coming to phones, but what about that tiny cell phone display? How can you use it to do real work? MIDs and UMPCs get away with running a full featured OS because their 4 to 5 inch displays present a miniature desktop. For many of these devices, the familiar Microsoft interface has been shrunk to fit pixel-for-pixel on the small screen. Anybody over the age of 40 who has tried to use such a device will realize how visually challenging it can be, particularly trying to select one of those miniature task-bar icons, so clearly there are fundamental user interface limits that need to be addressed. In an earlier introductory article ("Carry Small, Live Large," Jul.–Sept. 2007), I described how the input/output limitations of a small mobile device (Carry Small) can be overcome using a logical frame-buffer to render a full windows desktop in internal memory, and then view it wirelessly on a larger external disaplay (Live Large) though a Virtual Network Computing (VNC) protocol. For many applications, a modern WLAN provides more than enough bandwidth to support the VNC protocol. Figure 2 shows a simple implementation of this concept on an XScale-based cell phone running embedded Linux, connected to a PC through a Bluetooth wireless link. The phone employs an X-server rendering its Linux desktop into a logical frame-buffer, and a VNC server remoting the graphics

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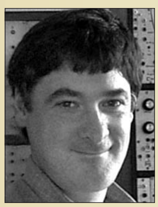
Figure 2. A Linux/XScale-based cell phone renders its desktop wirelessly to a nearby PC with a full-size display and keyboard, thus enabling effective user interaction.

NEW ASSOCIATE EDITOR IN CHIEF



IEEE Pervasive Computing is pleased to announce Joe Paradiso as a new associate editor in chief.

Joe is an associate professor of media arts and sciences at the Massachusetts Institute of Technology, where he directs the Responsive Environments Group, which explores how sensor networks augment and mediate human experience, interaction and perception. His current research interests include embedded sensing systems and sensor networks, wearable and body sensor networks, energy harvesting and power management for embedded sensors, ubiquitous and pervasive computing, localization systems, passive and RFID sensor architectures, human-computer interfaces, and interactive media. He is also serving as co-director of the Things That Think Consortium, a group of Media Lab researchers and industrial partners examining the extreme future of embedded computation and sensing.

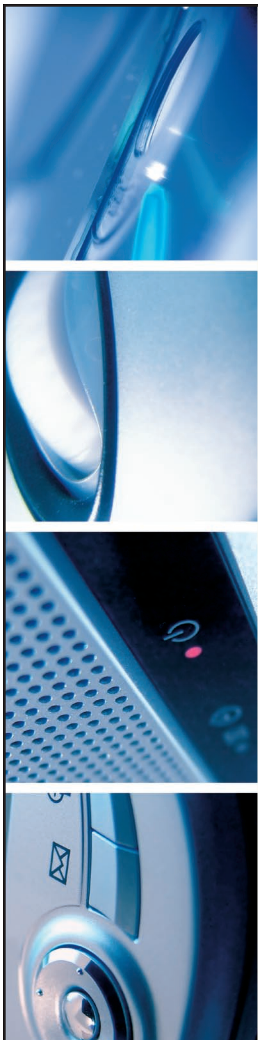
Joe fills in the gap left by the departing James Landay, who is stepping down after several years of service to *Pervasive*. We welcome Joe and thank James for his hard work on behalf of the magazine.

to a nearby PC running a VNC client. The demonstration shown has a few X-applications running to illustrate the concept: xterm, xcalc, xclock and xeyes. In all respects it is a fully functional computer except one: if you attempt to run a complex application, the processor and memory resources clearly struggle. The cell phone needs a high-performance processor to make this capability really useful.

In summary, Atom-powered cell phones are a likely consequence of the current mobile-processor design trends. By integrating a smart phone with a logical frame-buffer architecture and wireless display, they're well positioned to overcome current user interface limitations, and provide mobile users with a full x86 compatible PC experience. I work for Intel, so take what I'm saying with a pinch of salt. On the other hand, check out all the latest reviews of Moorestown, and judge for yourself. Is Atom just another processor family that will support a market for low-end laptops, or is it a game changer for cell phones that will revolutionize how we think about Pervasive Computing, and make smart phones even smarter?

ERRATUM

The last issue (vol. 8, no. 1) contained an error in the Works in Progress department, page 55. One of the coauthors of "RealNet: An Environmental Wireless Sensor Network" was José Polo and not José Garcia. We apologize for the error.



Call for Papers

VIRTUAL MACHINES IN PERVASIVE COMPUTING

Virtual machines provide a computing container that appears to be a physical computer and that can run a conventional OS and applications. Such virtual machines are now in wide use in data center and desktop computing, and multiple benefits are being realized from their use. These include the ability to easily encapsulate, deploy, clone, and manage applications, run multiple computing environments on the same system without sacrificing performance or security isolation, move running environments between systems, and recover quickly from hardware failures.

This special issue is focused on better understanding these complications, exploring solutions to them, and evaluating pervasive-computing specific benefits of virtualization. Example topics for this special issue include but are not limited to the following

- applications or services built on top of virtual machines, including Virtual Appliances, Virtual Appliance ensembles, and Virtual Desktop solutions
- creation and distribution of virtual machines including image management, end-user experience, payment models/mechanisms, patch and update mechanisms, and trust
- management of such deployed virtual machines including mechanisms for discontinuous management and digital rights management
- migration of virtual machines between mobile/ubiquitous devices including mechanisms for addressing virtual-machine data loss, network-speed discontinuities, and dissimilar platform capabilities
- security and privacy concerns from the perspective of users of virtual machines or computing platform providers including mechanisms for enforcing or increasing trust between these two groups

Submissions should be 4,000 to 6,000 words long and should follow the magazine's guidelines on style and presentation. All submissions will be anonymously reviewed in accordance with normal practice for scientific publications.

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