



the technology. Faculty comments afterward indicated that staffing was critical, and that the combination of a place for them to work and a full-time staff member on hand to help them with both the planning and the small vexations was what it took to complete their projects. Enough has been written about the support crisis in academic technology that it is easier for administrators to understand the need for staffing. In this case, the cost of dedicating a full-time staff member to supporting faculty development should be looked at in the context of the whole faculty and the whole curriculum. In that context, an incremental cost of less than 1% provides far more than that amount in benefits. The final chapter in our faculty development effort is not yet written, but the ability to reach a greater pro-

portion of the faculty this year, together with the earlier programs for access and academic facilities appears to be finally working to produce the desired result. ■

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The Future of Ubiquitous Computing on Campus

Mark Weiser

We are about to enter the third wave of the computing revolution. University campuses have been at the forefront of each of these technology revolutions.

The first wave constituted the mainframe era, and universities established glass-house computing rooms for students, faculty, researchers and administrators to benefit from this new invention. Universities adopted mainframe computers to class scheduling, and to physical simulations quicker than most industries. Our relationship to computers in this area was one of service: they were rare and expensive, and we serviced them.

The second wave, in which we are still deeply immersed, is the personal computing era. Instead of 80 tons, computers weigh 80 pounds (with monitor). Most students and faculty

can afford at least one PC; more often using several, in several locations. Our relationship with our PC is, well, personal. Sometimes we wish we were less dependent, that we could get along without this new unwieldy, noisy, unreliable, indispensable apparatus in our lives. Most campuses are still adapting to this era, and the PC wave will grow larger before it grows smaller as more and more students and faculty use laptops in their everyday work.

The third wave, just barely starting to break, is the era of ubiquitous computing. Computers can already be found in watches, toasters, ovens, cars, wallets, even in some campus ID. Inevitably these computers will become more pervasive, will talk to one another, and will form the invisible computational infrastructure of our lives. Our relationship to computers in the ubi era will be the inverse of the mainframe era: computers will be common and inexpen-

sive, and they will service us.

The campus environment will be a particularly good place for ubiquitous computing. Wireless communication will be key to tying together the diverse functions of the many computers around us, and a compact campus environment makes that easier.

A large factor in driving us to ubiquitous computing is the Web. The Web is essentially an agreement on how computers will talk to each other: thou shall speak IP, TCP, http, and html. Today, an 8-bit microprocessor can make an effective Web server for specialized pages, at a cost of only \$10. With this agreement in place, the cost to make Web-based information servers will continue to plummet, reaching a few cents in a decade.

The first harbingers of ubiquitous computing are already here. Small handheld computers are starting to be widespread. They do less than the

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hand-helds of a few years ago, but they cost less, and what they do, they do better. To understand how doing less can be an improvement, imagine a kitchen that contained a single appliance for cooking, boiling, chopping, toasting, and washing. It would be complicated, heavy, and lead to muscle strain when using it. Kitchens for thousands of years have used many different utensils to make the work easier. With ubiquitous computing, computers will start to catch up to kitchens. In order to have hundreds of computers serving us, each must be designed to provide just a few functions very well. Inside will be a general-purpose processor, but on the outside, unlike the PC, they will present an obvious and natural capability of doing one thing.

Today we carry a wallet with many credit cards. Imagine that each of those cards was a bright, easy-to-read computer display with a few buttons along the edge. What would they do?

The campus map card would always tell you where you are, and help direct you to new places. At your request, it would broadcast your location to your friend's map cards, so you could meet up.

The schedule card would show the location of your class. It might not be the same from week to week, since in the ubiquitous computing environment classrooms can be changed and students updated much more easily. (This change is analogous to, but goes somewhat further than, the change from departments teaching all classes in departmentally owned classrooms, to today's computerized room scheduling and classrooms in central classroom buildings, centrally scheduled.)

The food service card will not only let you buy food, but monitor your

diet, and show you the menu at the local eateries so you can choose where to go for lunch. It will also let you know the waiting time and the availability of seats before you arrive. This benefits both you and the eatery, to balance load.

In each class you will receive a card for that class. On it you can call up the homework assignments, instructor hours, and find your fellow students. You'll be reminded of tests in advance, and the card will wirelessly beam information into your PC for assignments.

Cards in your wallet will not be the only way that ubiquitous computing will be seen on campus. There will likely be wall-sized screens with electronic pens that can be used by multiple people. For late-night dorm brainstorming sessions, these boards will capture the great ideas, and also let them be shared with others.

A key concept of ubiquitous computing is to use technology to create a calmer environment. Minor frustrations—like long lines, missing classes or homework, finding friends—will be less frequent. To succeed at increasing calm, the technology will also need to stay out of the way. We say that it must engage the periphery of our attention, and not be the center of our attention. In that way our main focus can be the schoolwork or the person in front of us, while the computer almost imperceptibly aids our work.

As computing and information become more accessible everywhere, the value of physical presence and beautiful physical environments will increase. For the university, this may mean that their campuses that provide a respite and alternative to everyday business and home life may become their most important asset.

Computers can help a professor deliver a lecture remotely. But what a computer cannot transmit are the comfortable chair, the library ambience, and the discussion at the coffee shop after class where the real learning occurs.

The ubiquitous computing era also brings some dangers, the potential invasion of privacy being one of the more important issues. The computers around us will know much more about our location and our activities than they do now. Someone attempting to track us would have an easier time without some safeguards. Technically, the solutions are known. But we must have the will to use them in all computing devices, and firmly establish a right to privacy of all personal information on any computer, no matter who owns the machine. Even if the campus installs ubiquitous computing system, information about me on it should be mine. That is not the case today.

Over the next couple of decades the ubiquitous computing era will dawn and eclipse the PC era. Privacy concerns will increase, and these concerns will involve the best humanitarian and political thinkers on campus. In the end, PCs will move to the closet as personal servers, information will be available everywhere, and our ability to educate, and life in general, will get just a little easier. **G**

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