<< Return to article

WhereWare

Soon, hardware and software that track your location will be providing directions, offering shopping discounts, and aiding rescue workers—services that promise a windfall for ailing telecom carriers.

Illustration by John Craig.

By Eric W. Pfeiffer
September 2003

Amanda sits idly at the bar of the trendiest restaurant in town, twirling a swizzle stick and sipping a cocktail. But cool as she looks, she's feeling anxious: her date is nearly 15 minutes late. She considers calling him but doesn't want to seem nervous or overeager. Still, she pulls out her cell phone, only instead of calling, she opens a special menu, enters his number, and sees that he is at the corner of Prospect and Broadway, not more than three minutes away. When he walks in, Amanda brushes off his apology, saying she wasn't at all worried.

Sound fanciful—or outright implausible? Lock on to location-based computing, the hottest thing in wireless, which offers new services to customers and new revenue streams to carriers, and could save lives in the process. The idea is to make cell phones, personal digital assistants, and even fashion accessories capable of tracking their owners' every movement—

Finding Applications

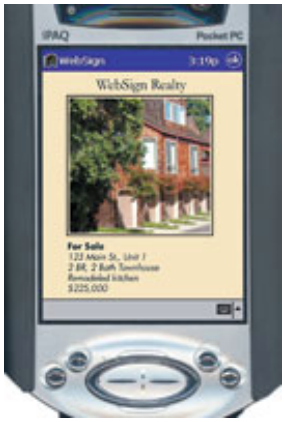
Technology firms and wireless carriers are racing to create services and applications that provide location-based information that customers will pay for. A few examples:

whether they're outdoors, working on the 60th floor, or shopping in a basement arcade. Already, Japanese telecommunications company KDDI offers over 100 different location-based services using technology developed by wireless-equipment maker Qualcomm, from bracelets to let parents track their kids in the park, to cell phones that point the way to cheap noodle shops in Tokyo's skyscraping Shinjyuku district. In Korea, two million citizens use their cell phones to locate nearby friends and, for example, find the most convenient coffee shops for impromptu meetings. In Europe, cell-phone networks can locate users and give them personalized directions to Big Ben, or the Eiffel Tower.

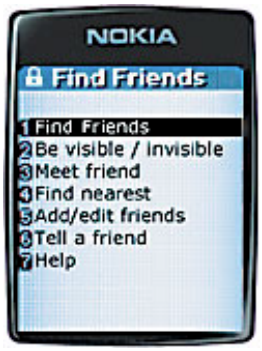
The U.S. is a bit behind the times: AT&T Wireless offers the hottest location-aware service, a friend finder, but only to a few hundred thousand of its 21.2 million subscribers. Market research firm Gartner, though, predicts that the number of American businesses and consumers using location-aware computing will skyrocket from 150,000 in 2002 to 42 million in 2005, with the market growing from $6 million to a whopping $828 million. Worldwide, Gartner estimates the market will exceed $26 billion by 2007. By then, or soon after, it's likely that devices will be able to locate people anywhere—at least outdoors—bringing the era of ubiquitous computing a giant step closer. In addition to helping stranded dates, shoppers, and hungry execs, location information could enable firefighters and other emergency personnel to find victims trapped in burning buildings. "Location-based services will become one of the fundamental services carriers will offer to their subscribers," says X. J. Wang, a senior analyst with the Boston-based research firm Yankee Group.

Given what's expected, it's little wonder that companies from Qualcomm to Intel, along with a host of startups, have jumped into the location arena. But the operative word is "expected." Before location-based services can truly find their way, a number of obstacles must be overcome. The technologies have yet to achieve the accuracy and consistency needed to deliver the most advanced services—especially indoors, where walls and other obstructions impede signals. Standards need to be established for steering location information across diverse wireless

Finnish company Ekahau makes software that can track users of Wi-Fi-enabled personal digital assistants and laptops through buildings such as shops or museums.



Hewlett-Packard's "Websign" technology embeds Web pages in the landscape, enabling users to find information relevant to their locations.



AT&T Wireless's "Find Friends" service allows customers to locate other AT&T subscribers in their areas.

Images courtesy of Ekahau, Hewlett-Packard and AT&T

networks, as well as for formatting data once it arrives at a cell phone or PDA. And privacy concerns are yet another potential stumbling block. Do consumers want even their friends to know their every move, let alone the folks at Starbucks? Or will users have the means to turn off location finding with the flip of switch?

Yet few in the field doubt that as the technology matures, such concerns will be dealt with. Consumers will then be left with a set of technologies working together to ensure that someone—or some network—always knows where you are, what you are looking for, and where you need to end up. Think of it as a permission-based Big Brother—an older sibling with a very good sense of direction.

You Are Here

Location-finding technologies have taken root in Europe and Asia (*see "Location's Rising Sun," sidebar*) due to the convenience they offer, but the driving force in the United States has so far been safety. Six years ago, the Federal Communications Commission mandated that cellular carriers be able to automatically locate anyone making an emergency 911 call. Carriers must be able to locate callers to an accuracy of 50 to 100 meters (depending on the technology used) by December 2005. "Hundreds of millions of cell phones have to have location awareness by law. That's a huge technology driver," says Larry Smarr, director of the California Institute for Telecommunications and Information Technology, which is helping develop, among other things, the next generation of wireless technologies.

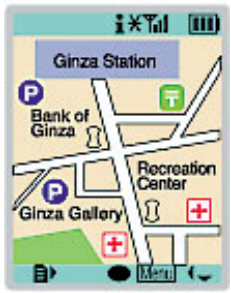
At the moment, though, just which location-finding technologies will win roles in this FCC-mandated infrastructure is unclear. Each has advantages and disadvantages, which often revolve around accuracy—how closely it can pinpoint a person's location—power consumption, and price. Each offers its own solution to the problem of tracking users as they move outdoors and in—not to mention the up and down problem of finding someone on the fifth floor versus the 55th. The final infrastructure "will be a combination of a bunch of different things," says Jonathan Spinney, a manager at Redlands, CA-based ESRI, a leading mapping and positioning company.

The first phase of the challenge—and the part farthest along—is outdoor tracking. Two of the most promising means for outdoor tracking are the Global Positioning System and existing cellular networks. The U.S. Department of Defense launched GPS in 1978 to enable precision weapons delivery; today thousands of GPS-equipped cars help civilians navigate the traffic-clogged minefields of city streets. Receivers fix position by calculating the travel time of radio signals to at least three of the 24 GPS satellites circling Earth in known orbits. Brad Parkinson, an astronautical engineer at Stanford University, was the first director of the GPS program, back in 1972. "Even at that time, we had a sense it would be very large, particularly for civil

Location's Rising Sun

By Bob Johnstone

NTT DoCoMo offers location-based business searches, eatery guides, and maps. (Images courtesy of DoCoMo)



Ren wants to meet his girlfriend at Z's, a bar in downtown Tokyo. She doesn't know where it is, so he downloads a color map to his cell phone and e-mails it to hers.

This has become a common scene in urban Japan since May 2000, when J-Phone, the country's third-largest wireless operator, launched J-Navi, Japan's first location-based service. Shortly after launch, J-Navi—which now gives directions to more than 15 million places of interest nationwide, including shops, cinemas, subway stations, and public toilets—was registering millions of page views. And it produced a veritable gravy train of revenue for J-Phone, a subsidiary of wireless conglomerate Vodafone, which charges subscribers for Web use as well as maps.

Japan's other two mobile-phone companies, KDDI and giant NTT DoCoMo, quickly followed with their versions of localized content, adding items like

applications," he says. "We also understood the location-based services that GPS enabled. But what turned out to be surprising is the accuracy we are now able to achieve."

That accuracy is now routinely within five to 20 meters, but because GPS requires a line of sight to the satellites, it doesn't work well in the urban canyons of large cities. To get around this shortfall, some wireless carriers employ a technology known as assisted GPS. Here, the existing cellular network augments GPS receivers, which can take a few minutes to locate satellites. The network speeds up this search-and-find process and helps GPS work in areas where it might not otherwise, identifying the nearest positioning satellites and acting as a sort of "You Are Here" sign. Korean and Japanese carriers have widely adopted assisted GPS, and as a result, Qualcomm has sold millions of GPS-enabled cell phones to Asian customers. In a similar approach—call it "TV-enabled GPS"—Rosum, a Redwood City, CA, startup, is using powerful broadcast television signals, as opposed to cellular signals, to triangulate position. Broadcast signals could be preferable to cellular because they already cover a wide geographical area and penetrate buildings more easily. Rosum has joined with Sunnyvale, CA-based GPS leader Trimble to integrate its technology with GPS.

But any variety of GPS requires that consumers purchase compatible handsets, meaning it could take years to build up a critical mass, at least in the United States. So some wireless carriers have developed ingenious ways to use their existing networks alone to pinpoint customers' locations. Because wireless-phone networks are broken up into individual cells that hand off calls to each other, which cell a caller is using gives a rough indication of his or her location. The accuracy, however, is poor—a Gartner report puts it at between 30 and 150 kilometers, depending on conditions. If you are looking for a Chinese restaurant in New York, that's a lot of egg rolls to choose from.

restaurant guides, weather forecasts, and train timetables. Dozens of other mobile-Internet services that exploit location information have sprung up since.

"Carriers and their content providers alike have all enthusiastically adopted [location-based services]," says Daniel Scuka, business manager of *Wireless Watch Japan*. "Determining where a mobile user is has become a fundamental element of planning any new content, application, or service."

Actual numbers are hard to pin down, but estimates put regular users of Japan's location-based services in the tens of millions. Gadget-loving young Japanese like the services because they are cheap (in some cases free), easy to access, and convenient. The most-used services are maps, navigation, and area information—data on which restaurants and shops are nearby.

Location determination techniques range from no-tech to high-tech. In no-tech, phone users register their home locations, and providers send content to their phones—say, discount coupons to local video stores. High-tech employs the one-touch Global Positioning System handsets that carriers began selling last year, so that services can be tailored to a user's up-to-the-minute location. KDDI has sold about five million of the phones in their first year of availability.

For most purposes, however, low-tech triangulation using cell towers is accurate enough. Users can opt to receive marketing messages with coupons or promotional offers—the real gold of the mobile Internet—within certain areas. In March, J-Phone launched Loco Guide, which broadcasts a wide range of information to customers based on their current locations, including details on upcoming concerts, movies, and other events. In Japan, it seems, Big Brother is more interested in pitching you than watching you.

A method called "time difference of arrival" can narrow things down. Similar to GPS triangulation, this approach plots location by measuring the exact time it takes for a signal from a cell phone to travel to three or more cellular base stations and calculating the differences. If only two cell sites are present, which is often the case in rural areas, then the angles of the arriving signals can provide the additional position information instead.

Unlike Asia, where the clear winner has been assisted GPS, the United States is seeing a hybrid approach: AT&T Wireless and Cingular, for instance, are using time difference of arrival, while Sprint and Verizon employ assisted GPS.

But while cellular location technologies don't require customers to buy new equipment, they still

aren't as accurate as GPS—with resolutions of only about 120 meters, according to ESRI's Spinney. Although this is enough to meet government 911 mandates, it is not accurate enough to offer navigational services. Which is why Spinney believes that in the long run, assisted GPS will prevail globally. "Everything will go to assisted GPS," he says.

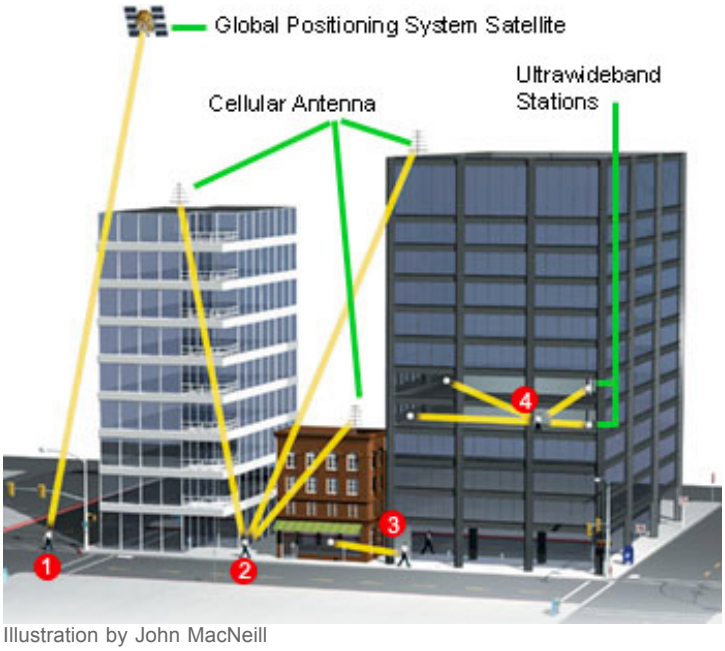


Illustration by John MacNeill

A combination of technologies such as the Global Positioning System, cellular triangulation, Wi-Fi data networks, and ultrawideband triangulation will create the outdoor/indoor tracking infrastructure of the future.

	1	2	3	4
	Global Positioning System (outdoors)	**Cellular Triangulation (outdoors/indoors)**	**Wi-Fi Networks (indoors)**	**Ultrawideband (indoors)**
Precision	Five to 20 meters	Down to 120 meters	One to 20 meters	Several centimeters
Companies	Trimble, Rosum, Qualcomm, Sprint, Verizon	AT&T Wireless, Cingular	Ekahau, Accenture, Symbol Technologies, Transat Technologies, UPS	Pulse-Link, Æther Wire and Location, U.S. military

Moving In

Tracking users becomes much more challenging indoors, however. Assisted GPS can lose much of its accuracy due to ceilings, walls, and other obstructions, while cellular techniques don't even come close to making the grade: a 120-meter error range may let you spot a flashing restaurant sign down a city block, but even a five-meter miss in a skyscraper could put a user on a completely different floor. Although this isn't an issue in many applications, it could mean the difference between life and death to soldiers trying to identify friends and foes in an urban warfare setting or firefighters searching for victims in a blaze.

So what kind of technology could be used once a person steps inside and takes the elevator up, up, and away? One possibility is the popular wireless networking technology known as 802.11, or Wi-Fi. Numerous wireless carriers have begun installing Wi-Fi transceivers in hotels, cafés, and other commercial buildings to deliver high-speed Internet access to mobile users. This expanding infrastructure can also be used to locate people indoors, says Antti Korhonen, CEO of Helsinki, Finland-based Ekahau, which builds software that enables Wi-Fi location finding. This past spring, consulting firm Accenture used Ekahau's software in a pilot project for New York's Metropolitan

Museum of Art: patrons wandering the Met's cavernous halls and stopping at a few of its two million works of art received information about the pieces in front of them with the click of a PDA button.

To achieve this virtual docent delivery, Accenture employees drew a detailed map of the exhibit area—a process that can take an hour for every 1,000 square meters covered, says Korhonen. Once the map was uploaded into a computer, employees walked around the museum, clicking on the map every three meters and recording the network's signal strength. Each location was matched to a specific signal strength, so that when museumgoers accessed the network, it knew where they were. With accuracy ranging from one meter to 20 meters, says Korhonen, Wi-Fi mapping is generally more precise than cellular triangulation. Big commercial applications will begin to emerge this year, he says; for instance, a German retail chain is using Wi-Fi in a pilot project to push information to shoppers depending on their location in a store. Since devices on the first floor of a building will measure significantly different signal strengths than those on other floors, Ekahau's technology can also solve the up-down problem, says Korhonen. "There is no way we could miss the floor," he says.

If location is calculated based solely on which Wi-Fi access point is closest, though, and not on painstakingly assembled signal-strength maps, the technology often places people on the wrong floors. And whether used indoors or out, a Wi-Fi transceiver covers a limited geographical area, with a radius of only about 90 meters. It's also susceptible to signal interference that can affect accuracy and is not particularly secure: nefarious characters might be able to determine your location based on your signal. According to Bill Yeager, a Sun Microsystems engineer working on location-aware computing, someone who knows that you are in a pizza place rather than at home could say, "Let's go over there and steal his home theater, or whatever they want to take."

It's not hard to imagine applications that will require greater accuracy, not to mention reliability and security. Luckily, another wireless technology could fill the gap: ultrawideband. Ultrawideband uses on/off energy bursts only billionths of a second long at extremely low power (one-thousandth the power of a traditional cell phone) over a large frequency spectrum. These tiny bursts enable the technology to deliver data at speeds of hundreds of megabits a second, as well as provide ultraprecise positioning. And as with GPS or Wi-Fi, ultrawideband could be incorporated into a cell phone or PDA.

Distance can be determined by measuring how long it takes a pulse to travel between an ultrawideband transmitter and receiver, and position can be determined via triangulation if at least three signals are received. "If you have four locations, you can do vertical mapping," says Bruce Watkins, president and chief operating officer of Pulse-Link, a San Diego-based ultrawideband company. That enables the system to figure out how high an object is off the ground—or which floor of an office building or hotel a person is on. Because the technology—unlike Wi-Fi—relies on ultrashort pulses, the receiver can determine time of arrival in picoseconds, allowing it to establish location to within centimeters, according to Watkins. Yet because ultrawideband is not as far along in its development and deployment as Wi-Fi, ESRI's Spinney, for one, sees it losing out on many applications, such as tracking consumers through malls or airports—where Wi-Fi systems are already being installed—and sending them promotional offers.

The Perfect Hand-Off

In an ideal world, a cell phone or PDA would seamlessly switch from, say, GPS to Wi-Fi when its user walked indoors, providing continuously updated location information. In the real world, though, the pieces still don't quite fit together. "We have a whole tool chest of location technologies, but what there isn't is a unified go-anywhere approach," says Smarr of the California Institute for Telecommunications.

Generally, the problem isn't technological: Wi-Fi and cellular radios, for example, can be integrated into a single device. Symbol Technologies, a Holtsville, NY, mobile-computing company, has developed a handheld for UPS that can access both types of networks. The difficulty lies in setting up service plans and contracts that will allow users to get location-based services as they move from outside to indoors. Cellular and Wi-Fi integrator Transat Technologies, in Southlake, TX, and Gemplus, a leading smart-card company based in Luxembourg, have begun to tackle the problem with special software embedded in smart cards. As carriers start to offer both Wi-Fi and cellular services, mobile users will be able to plug these cards into their cell phones and get access to both types of networks—and, presumably, all the location-based services they make possible.

In the shorter term, however, an even bigger problem looms: what if callers want to access location-based services using multiple cellular networks, say, AT&T Wireless and Sprint PCS, as opposed to a single carrier's combined Wi-Fi/cellular network? Software standards that will allow callers to use location-based services across the two main U.S. cellular technologies (which are known by the acronyms CDMA and TDMA) were expected to be ratified by this fall, according to Paul Hebert, a senior product manager at Redwood City, CA-based Openwave Systems, which sells location-based applications to carriers. Similar roaming standards for GSM, the world's other major wireless standard, could be approved next year, he says. The lingering question, though, is whether carriers will share their services with other companies' customers. "For location services, it is the business issues that need to be resolved," not technological ones, says Hebert.

On the assumption those business issues *can* be resolved, Intel is pushing to enable even greater interoperability across technologies. While the proposed standards would allow callers to use location-based services offered by different cellular networks, Intel's idea is to let them switch just as effortlessly between cellular, Wi-Fi, and ultrawideband networks. Intel's "location stack" system will also be able to compensate for the imprecisions of the various technologies to yield more exact position information, says Gaetano Borriello, director of Intel Research Seattle. "The reason we are pushing the stack model is to keep [location finding] independent of a specific technology," says Borriello. "We want to provide the infrastructure that will allow others to experiment and find those killer apps."

Killer Apps?

Once the location-finding infrastructure and standards are in place, experts say, the U.S. market for location-based services will take off. Offerings will, no doubt, include friend and noodle finding, but a variety of other services are in trials or still on the drawing board. While everyone has a best guess as to what the real killer location application will be, they remain just that—guesses. "There are going to be things that just pop up," says Borriello.

At their core, the winning services will give people information that improves lives and saves time, or as ESRI's Spinney puts it, that "predicts the unpredictable"—enabling, for instance, easy navigation around traffic accidents or street closures. Because outdoor location-finding technology is more mature, services such as friend or restaurant finding have been offered first. But carriers see these as just the first wave of a variety of location-based services that "they can sell to drive revenue," says Arnold Gum, a Qualcomm senior product manager whose job is to

figure out how new technology can help the world's wireless carriers make more money. In some cases, customers will be charged by how much data they consume: users of AT&T's friend finder service, for example, pay $2.99 a month plus usage charges, which depend on how many friends they ping. In other cases, consumers will be charged a set fee for each application.

So what other services would consumers, businesses, and even governments be willing to pay for? A PDA or cell phone that knew its location might display highly localized weather forecasts: "Severe thunderstorms south of the interstate by mid-afternoon." Minnetonka, MN-based Digital Cyclone is developing software that in the next few years will do just this, using GPS- and Internet-enabled mobile phones (*see "Pinpoint Weather," TR June 2003*). And if those severe thunderstorms happen to spawn high winds and lightning strikes, setting fire to a building, ultrawideband might help locate people trapped inside and track firefighters maneuvering to help them. "With this technology you'd know exactly where they are," says Pulse-Link's Watkins. He believes such a deployment is still a few years off, although the U.S. Department of Homeland Security is actively investigating using ultrawideband in emergency situations.

The U.S. Defense Advanced Research Projects Agency also thinks enough of the technology that it has provided most of the $7 million funding for Æther Wire and Location of Nicasio, CA. CEO Patrick Houghton says his firm has built pager-sized demonstration devices that will locate soldiers—and anyone else—within a centimeter of accuracy over kilometers of distance.

Looking even further out, Salil Pradhan, a manager and senior scientist at Hewlett-Packard Labs, has developed "Websign," a technology that automatically delivers Web pages to cell phones or PDAs—but not just any Web pages. The links to these pages are "embedded" in the landscape itself. Take, for example, the popular Sunday excursion of house hunting. In Pradhan's world, your GPS-enabled cell phone would report your location within a certain city block. When you point the phone at a realtor's for-sale sign, up pops a detailed description of the home behind it. Walk through the front door and an indoor technology like Wi-Fi takes over, telling you all sorts of interesting things as you wander from room to room—say, who the agent is, the age of the roof, or when the kitchen was remodeled.

The Privacy Problem

Susan Landau is a senior staff engineer at Sun Microsystems Laboratories, which has launched a major project on location-aware computing. Landau, who researches privacy and security issues related to new technologies, addresses three questions.

Technology Review: New technologies frequently raise privacy issues. Are there privacy concerns unique to location-based services?
Susan Landau: We've grown up with one model of the world, which is that you don't broadcast where you are. When you say, "I'm on my way home," nobody knows that you did a three-block detour to pick up flowers or mail a letter to somebody you weren't claiming to be in communication with. Is it impossible to live in an environment in which your cell phone and your PDA [personal digital assistant] give away your location? No. Is it an infringement of privacy? Of course. How will people react? The balance between privacy and convenience is different for everybody.

TR: Does broadcasting location also become a security problem?
Landau: Before September 11th, we saw it as a commercial privacy issue: did I really want to have the advertisement from the pizza joint flash onto my cell phone as I was passing? But now it's a very important security issue as well. This makes cell phones in some ways less useful to people. So one imagines, for example, that certain people should not be carrying cell phones, or at least should have their phones turned off. A congresswoman such as Nancy Pelosi is a good example; one would not want her to be broadcasting her location.

TR: So how do we deal with this?
Landau: Users should be in control at all times of giving out personally identifiable information—in this case, location. You want to include the capability to choose who can access your location information. You want the ability to give only limited access to the information to some individuals, maybe only certain hours of the day, or certain times of the week. For example, your boss might have access to your location information during working hours. Good privacy design might include requiring proofs of identity before location information is revealed. And you have to design the technology deciding what you

Future Directions

want your privacy policies to be, what you want to enable. Because if you don't put those designs in at the beginning, then you may have locked yourself out of that capability.

As our networks and devices get more adept at pinpointing our locations, a question naturally presents itself: are we sure we want them to? Location-based services could be a boon to consumers and carriers alike, but only if the pesky problem of privacy is addressed first. We don't want even our friends to know where we are at all times, let alone advertisers wanting to send us coupons. Sooner or later, and probably sooner, consumers will demand the ability not to be found. Even GPS coinventor Parkinson has concerns. "In five years, location-based services will become much more insidious than they already are. There's no doubt about it," he says.

Qualcomm's Gum understands the need for privacy and believes the best answer is giving consumers the ability to turn location finding off at their handsets, which Qualcomm's technology does. Similarly, AT&T's friend finder service offers users the option of being "invisible." In addition, the servers that deliver location services can be programmed with strict rules on who can find whom and when (*see "The Privacy Problem," sidebar*).

In the long run, those in the field believe the advantages of location-aware computing far outweigh the disadvantages. "There is a lot of cool stuff you can do with location," says Gum. For one thing, he predicts, we will forget about road maps or directions and let technology worry about where we are. "I won't have to pay as much attention to street signs," he says. And in the future, he adds, our cell phones will even figure out when we are heading home and notify our home servers to turn on the lights. Within five years, agrees Spinney, location finding will become ubiquitous. "It is just going to be out there, and any application developer will be able to grab it and use it. Once that opens up, you have the potential for things to really explode." Then we may never be lost again.

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