Pervasive Tabs, Pads, and Boards: Are We There Yet?

How far have we come with respect to commercial deployments of the devices Mark Weiser described? This review of Weiser's vision evaluates the commercial success of tabs, pads, and boards and discusses their real-world use.

Maria R. Ebling
IBM T.J. Watson Research Center

Mary Baker
HP Labs

In 1991, Mark Weiser described the most profound technologies as those that disappear by weaving themselves into "the fabric of everyday life until they are indistinguishable from it."[1] His vision for ubiquitous computing was one where we could live comfortably and more productively because we'd be surrounded by computers that help us yet disappear into the background.

On the 10th anniversary of Weiser's publication, *IEEE Pervasive Computing* examined how far we had come. Nigel Davies and Hans Gellersen reviewed deployments of ubiquitous systems coming out of a number of research labs,[2] including the Lancaster Guide system,[3] the Cooltown project,[4] and the MediaCup work.[5] Now, on the 20th anniversary, we review how far we've come with respect to commercial deployments of the devices Weiser described.

As Weiser explained, "My colleagues and I have built what we call tabs, pads, and boards: inch-scale machines that approximate active Post-It notes, foot-scale ones that behave something like a sheet of paper … and yard-scale displays that are the equivalent of a blackboard or bulletin board."[1] Here, we look at these three scales of computing machines, examining their use in the real world and forecasting their future potential. We find that although we've traveled a long way toward achieving Weiser's vision, we have yet to reach our destination.

Inch-Scale Machines

Today's "inch-scale machines" come in many forms, from the active badges that Weiser described in his article, to smartphones, which could be considered the direct descendants of Weiser's tabs. But today's inch-scale machines go beyond badges and tabs to include devices such as wristwatch computers, sensor motes, MP3 players, and handheld games. Inch-scale computers are almost ubiquitous, but compared to Weiser's vision, most are used less as badges or for sensing or controlling our environment and more for personal productivity, entertainment, and communication. (See the "Commercial Offerings" sidebar for product information on devices mentioned throughout the article.)

Active Badges

An active badge is about the size of an identification badge and can be clipped onto a lapel.[6] The badge can communicate with receivers placed throughout a building or facility, notifying a computing system of its location. The system can then map badge ID numbers to employees to locate people throughout the building. Initially developed by the Olivetti

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Commercial Offerings

The following is a list of the commercial offerings discussed in the article (in order of appearance) that aren't referred to in citations at the end of the article.

Inch-Scale Machines

i'm Watch: http://live.imwatch.it/
ActiveWave RFID Active Tags: www.activewaveinc.com/products_active_tags.php
Radianse ID Tags: www.radianse.com/products_tags.html
Arch Rock motes: www.cisco.com/web/about/ac49/ac0/ac1/ac259/archrock.html
MOOG Crossbow motes: www.xbow.com
Fruition Sciences sensor nodes: http://fruitionsciences.com
Sifteo cubes: www.sifteo.com

Foot-Scale Machines

Amazon Kindle: https://kindle.amazon.com
Barnes & Noble Nook: www.barnesandnoble.com/nook
Apple iPad: www.apple.com/ipad
Samsung Galaxy: www.samsung.com/us/mobile/galaxy-tab
Jeppensen Mobile FlightDeck: http://ww1.jeppesen.com/apps/mobilefd
Deploid Tablet PC Menus: www.deploid.com/tablet

Yard-Scale Machines

SmartBoard: http://smarttech.com
Promethean ActivClassroom: www.prometheanworld.com
Hitachi StarBoard: www.hitachisolutions-us.com/starboard
Cisco TelePresence: www.cisco.com/en/US/products/ps7060
Polycom RealPresence: www.polycom.com/products/hd_telepresence_video
AdSpace Digital's Mall Network: www.adspacenetworks.com/index2.php
Appliance Studio PrintSign: www.ambientweb.co.uk/sectors/smartsigns.htm
Dynamax POV system: www.dynamaxworld.com/Solutions-Vertical-Sectors.html
Haivision CoolSign: www.haivision.com/products/CoolSign_Cool-Sign
Sony Ziris: http://pro.sony.com/bbsc/ssr/cat-digitalsignage/resource.articles
eKiosk Phex Digital Signage: www.ekiosk.de/en/digital_signage_system_phex.html

Cambridge research laboratory, active badges are now offered by numerous vendors (such as ActiveWave and Radianse) in various sizes using several different communication frequencies.

The deployment of active badges at Xerox PARC led to articles concerned about Orwellian futures.[7] In fact, active badges aren't widely used in businesses today in the way Weiser envisioned, primarily because of privacy concerns and a weak business case. However, active badges have found a niche in industries involving safety, where the business case is stronger and the privacy concerns are weaker. In particular, hospitals have used them to track expensive equipment, and manufacturing plants have used them to enhance worker safety by tracking heavy equipment and people.

For example, Saint Michael's Medical Center uses ultrasound tags to monitor the location of 1,500 mobile, biomedical assets. The ability to locate biomedical assets quickly lets the center's technicians comply with preventative maintenance requirements, identify equipment recalled by the manufacturer, find equipment with expiring leases for timely returns, and identify idle assets. We spoke with Maria Agostinho, the center's Director of Biomedical Engineering, who said they've been able to "significantly reduce" the amount of time it takes to find equipment and have "increased their equipment utilization." Agostinho can't imagine going back to using the "Easter egg" hunting method of tracking equipment.

Posco Steel Mill, the fourth largest steel manufacturer in the world, is also using active RFID tags.[8] At their Finex plant, located in Pohang, South Korea, they've embedded the active tags in the hard hats that visitors and employees wear. This helps Posco's managers quickly locate people in an emergency. The tags also help Posco monitor equipment. The monitoring system can generate an alert if a person enters a restricted area without the proper equipment. For example, certain sections of the plant require a gas monitor. If someone tries to enter such sections without a monitor, or if the person wanders too far from the monitor, the safety system sends an alert. In addition, the plant can save electricity by reducing lighting when no one is around, as determined by the active tags.

Smartphones

Today's smartphones act as email readers, calendars, diaries, and entertainment systems, and they can provide almost constant connectivity between people via texting, voice calls, and video conferencing. These phones have become so ubiquitous that networks within buildings, such as those in conference rooms, at times can't handle the hundreds of "computers" attempting to gain access simultaneously.

Orwellian or not, many applications and services track our location through smartphones, often to support

Figure 1. Sifteo cubes. They know their relationship to one another, allowing them to appear to interact with one another.

end-consumer applications and services. Smartphones know their location and react accordingly. Phones can display maps with a pin to show the phone's current location and can help their owners navigate to other locations. They can show restaurants, gas stations, and other points of interest near the phone's current location. They can show us where our friends are located, where people with similar interests congregate, what businesses they patronize, and even what they're doing.

Car Navigation Systems

Car navigation systems also exhibit the navigation functions just described and are technically inch-scale computers. Most car navigation systems obtain their location from satellites and don't have a communication capability to disclose their location externally, so they suffer less from privacy concerns. They represent an appliance that has disappeared into the background (more so than smartphones) for drivers in familiar and unfamiliar areas alike. However, despite these advantages, car navigation systems compete with smartphones, and smartphones offer many additional features beyond navigation.

Smart Dust

Smart dust,[9] best exemplified by sensor motes (for example, Arch Rock's or MOOG Crossbow's), can be carried with the item being sensed, such as when the mote is monitoring a piece of equipment or a shipping container. In this capacity, they act a bit like a smartphone or active badge. However, they can also be positioned in the environment—to monitor the geological activity of a volcano, for example, or a grapevine in a vineyard.

Fruition Sciences is attaching sensor nodes to grapevines, connecting the sensors via a mesh network and providing winemakers with a dashboard to help them better care for their grapes (http://fruitionsciences.com). Sap-flow sensors, installed on the vines, send wireless readings of how much water is moving through the vine—its "transpiration rate." The system also collects information from weather stations positioned throughout the vineyard. The data is aggregated into a reporting tool to help the winemaker manage the vineyard, determining whether, when, and how much to irrigate the vines.

Austin Peterson, Ovid Napa Valley's winemaker, has used this system since 2008. He says that the system "is an incredible tool and tremendously helpful. It allows better control of the irrigation system to meet the needs of the grapevines and improve the quality of the fruit." Interestingly, when asked about the technology, Peterson said he wasn't versed in the details and pointed us to Fruition Sciences for more information—a direct testament to this technology disappearing into the fabric of everyday vineyard management.

Sifteo Cubes

As a final example, let's look at Sifteo cubes (www.sifteo.com), a type of inch-scale computer used for entertainment and education. These cubes, shown in Figure 1, know their relationship to one another, allowing them to appear to interact with one another. The cubes offer several games designed to challenge the brain. The cubes are wirelessly tethered to a laptop or desktop computer that coordinates the game and provides sound. This type of device is one we could see sprinkled about the environment and left behind for others to use because it isn't as personal as many of the others.

Assessment: Mixed Results

The inch-scale computer has come the furthest in achieving the ubiquity Weiser envisioned. The active-badge concept itself is far from ubiquitous but has found a niche in specific applications such as tracking things as opposed to people—or tracking people in hazardous environments. Smart dust takes the active-badge concept a step further, allowing more sensing capability in a somewhat smaller package. It too has found a niche—again monitoring things as opposed to people. Navigation devices are common in cars and, unlike active badges and sensor motes, are used by consumers to get from one location to another—even by consumers who aren't necessarily comfortable with computers.

Mobile phones, however, have clearly achieved the distinction of becoming ubiquitous in the past 20 years. As of November 2010, in the US, 234 million Americans aged 13 and older use a mobile phone, and more than 61 million use a smartphone.[10] In addition to providing the types of

capabilities available on an active badge, a sensor mote, or a navigation device, mobile phones also provide the killer app—the ability to communicate with anyone wherever you happen to be (as long as you have wireless coverage). The mobile phone has achieved the goal of ubiquity, although perhaps not the goal of fading entirely into the background.

Weiser's vision also included an expectation that computing devices would move away from being personal to being environmental. On this dimension, inch-scale computers have had mixed results. Some applications, such as smart dust and environmental sensing, are clearly nonpersonal devices, deployed throughout a limited environment. On the other hand, smartphones are very personal devices, akin to a wallet. These devices aren't left lying around, except by accident.

As we look into the future, we anticipate that smartphones will continue to increase their capabilities and their foothold in our lives. We expect to see more smartphones being used to pay bills in the US, such as the recent beta test at Starbucks.[11] (This is already common in other countries.) We expect smartphones to become more aware of social and environmental context and to adapt their behavior and the services they provide accordingly. We also expect to see more integration of smartphones with enterprise business applications as well as more use of smartphones instead of laptops for a variety of business applications, including email.

Foot-Scale Machines

The second scale of machines that Weiser identified is the foot-scale machine—one that acts like a cross between a piece of paper and a laptop computer. Weiser described these machines as having a paper-sized screen that could be used to extend the work area of a traditional computer screen. His view was that they would be left scattered about a home or office to be used at will. He argued that if people felt the need to carry such a pad around from room to room, then the pad was a failure. Weiser's standard for success might have been a bit high, considering that, by this standard, a pad of paper would be a failure.

Reading Appliances

Today, many foot-scale devices are available. We have reading appliances, such as the Amazon Kindle, introduced in 2007, and the Barnes & Noble Nook, introduced in 2009.

People no longer think of their readers as computers. They pick them up and naturally turn them on (instead of opening them), click a button or touch the screen (instead of turning the page) and annotate them (instead of writing notes in the margin). Sharing books is both easier and harder. It's surprisingly easy to share annotations, especially from some readers. It's more difficult to share a book, but it's becoming easier to check one out from the library.

Content isn't universally available, but it's becoming more common. Book publishers are publishing many, but not all, books electronically, and newspapers and magazines are publishing electronically as well as on paper. In late 2009, Amazon announced that sales of electronic books exceeded sales of paper books on Christmas day.[12] Although that was probably anomalous because of the holiday, it was a sign of things to come and a trend that has continued.[13]

Wendell Baker, a computer scientist employed by a San Francisco Bay-Area Internet search company, began reading newspapers and other periodicals on his Kindle several years ago and ceased reading paper copies. He explained to us that the form factor of the electronic reader is more convenient than paper copies, and it's much easier to avoid the copious advertising found in print. Also, he finds it easier to scroll through the news stories electronically than to search the paper layout to find the headlines of interest. He notes, "there's a lot less news in a newspaper than you'd think, and this becomes apparent when you access the news from an electronic reader." Interestingly, he only reads electronic newspapers in the kitchen in the morning, in the same way he used to read the print newspaper. Other periodicals—ones that benefit from color graphics, sound, and videos—he reads anywhere, whenever convenient, on a tablet computer.

Pad-Style Appliances

Pad-style appliances include Apple's iPad and Samsung's Galaxy Tablet, both introduced in 2010. Businesses have started to integrate these devices into their operations.

One example is Jeppensen's Mobile FliteDeck, which provides a mobile-enabled paperless application for pilots (see Figure 2). The system provides images, dynamic flight data, and an extensive global chart library. The system eliminates, for instance, the error-prone and time-consuming need for pilots to update daily their cockpit binders of information regarding changes to landing and take-off instructions for airports around the world. The application is designed to work on an Apple iPad and is a good example of how businesses are exploiting such devices.

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Assessment: Not Yet "Scrap" Computers

Today, foot-scale devices are typically personal devices, owned and operated by individuals or shared among

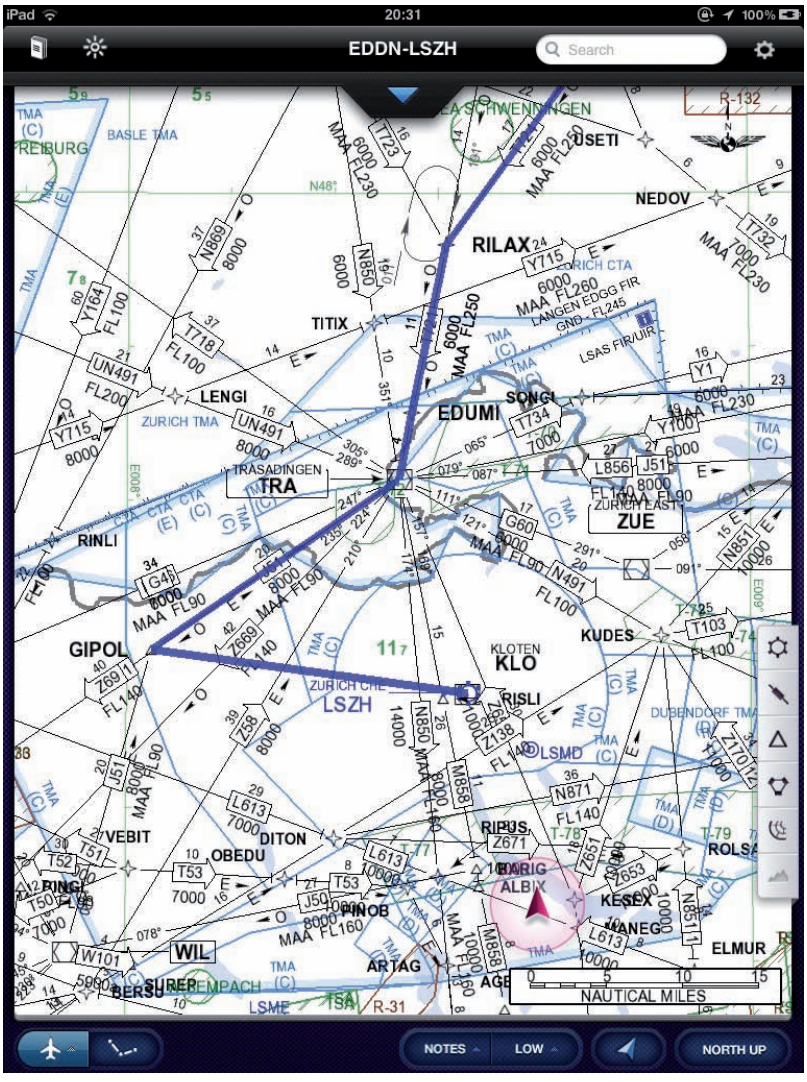


Figure 2. The FliteDeck application. This mobile-enabled paperless application for pilots provides images, dynamic flight data, and an extensive global chart library.

family members. They might be left laying on a coffee table, but they're not so numerous that they can be used as the "scrap" computers Weiser envisioned, left behind for the next person. Except for some in situ business uses, such as the Deploid, tablets tend to be carried from location to location by their owners. High prices and customization (by way of downloaded apps) play a part in this. Until it becomes trivial to access our personal environments and activities from any machine, we expect pads to remain personal devices, carried from place to place.

Foot-scale devices are on track to fade into the fabric of everyday life, but they might never reach Weiser's ultimate goal of being used like a sheet of paper. Because most people tend to have just one or two foot-scale devices, they don't "spread the many parts of the many tasks of the day out in front" of them as Weiser envisioned.[1] Instead, they use these devices as readers and as more portable laptops. Whether we'll move closer to Weiser's vision as prices come down and as cloud computing becomes more useful is unclear. The limited success of community bicycle and car programs is a testament to the fact that people like to "own" their mobile equipment.

As we look to the future, we expect foot-scale devices to become even more pervasive. As prices come down, more paper-based reading material will be accessed digitally. In particular, more students will start using electronic textbooks in the coming decade—in fact, several communities are already exploring this option.[14]

The foot-scale machine is immature. People are using these machines differently from what they expected when they purchased them. In addition, businesses are still figuring out how to integrate them into their enterprise. Consequently, we expect this market to evolve over time, and foot-scale machines should eventually gain significant market share over laptop computers.

Yard-Scale Machines

Weiser also envisioned the "board," intended to serve as a video screen, bulletin board, or whiteboard in the home or office. The board had a large screen, approximately 40 × 60 inches, controlled by both a keyboard and an electronic pen. Numerous prototypes were placed around the offices at Xerox PARC, allowing researchers to experiment with them. Weiser envisioned these boards serving as collaboration tools. In fact, the boards at Xerox PARC were used for impromptu collaboration, even occasionally between labs separated by the Atlantic Ocean.

Interactive Whiteboards

Several companies around the world manufacture yard-scale devices similar to those prototyped by Weiser and his colleagues at Xerox PARC—including SMART Board, Promethean, and Hitachi's StarBoard. These systems

offer an interactive whiteboard that lets teachers create dynamic lessons and vivid multimedia presentations. They support team collaboration and allow notations using electronic ink. Although the boards are rarely seen in homes and aren't extensively available in corporate offices, they're becoming more common in school classrooms.

Linda Guzzo, a fifth-grade teacher at Kensico School in Valhalla, NY, explained to us that the board makes her classroom more interactive by letting students manipulate objects on the board through a touch-screen display. She thinks that the board makes learning fun and more like the technologies that the kids use at home (see Figure 3). "The board has changed the way I teach and the way my students learn," said Guzzo.

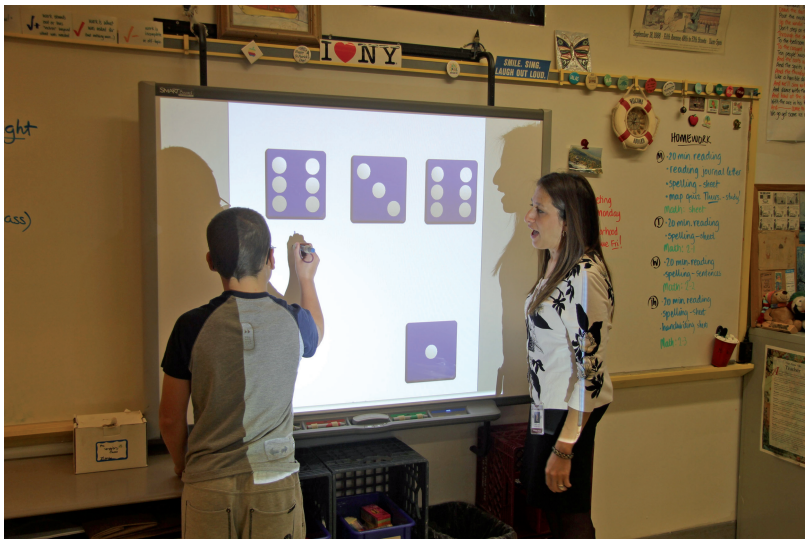


Figure 3. A teacher and student focus on math using an interactive whiteboard. Such boards are becoming more common in schools.

For students, the technology behind the boards fades into the background. The students don't think of the board as a computer—just as a fun way to learn. Guzzo explained that the teachers know very well that there's a computer running the board because they have to "program" the lesson plans. Guzzo seemed amazed at the board's capabilities and is continually learning more ways to use it in her classroom. She envisions using the board to collaborate with children in other countries.

Some boards have integrated handheld units for each student that let the students respond to a prompt, such as a quiz. These devices let the teacher quickly see how well each student is grasping the material. They begin to support Weiser's view of devices interoperating with one another, but we still have a long way to go. Although these boards have been used mostly in schools, some companies have adopted them as well. Turner Construction Company uses Smart Board technology to enhance their building process, making it more efficient and of a higher quality.[15] Dan Gramer is a national manager with the Turner's Integrated Building Solutions team. He explains, "Smart Boards have changed our meetings. We're able to get on topic, pull up a 3D model, show the problem, and quickly get others on board. Everyone in the room can quickly understand what the issue is and collaborate on resolving it."[15] Once all parties have agreed on a solution, the team uses the board to sign off on the plans right on the screen. By the time the parties return to their offices, they have a copy of the new plans waiting on their computer. This type of technology has also proven effective in helping to manage complex projects. Turner attributes a US$2 million savings on one project to the use of technologies including SMART boards.

Telepresence

Although yard-scale displays in corporate offices aren't widely used as the interactive, collaborative "whiteboards" that Weiser envisioned, they're used extensively in this environment as telecommunications products. For example, Cisco's TelePresence and Polycom's RealPresence use large displays and advanced computing techniques, such as automatically encrypting both the video and call signals to provide secure and confidential communication. These screens support face-to-face meetings without requiring time-consuming and costly air travel. Shared materials such as slides and documents are typically displayed on an additional screen or in the same manner as the participants—with the camera focused on the materials. In essence, they're acting as video displays to bring people together.

Furthermore, computing moves into the background in these systems, at least when the technology is working as designed. Participants in high-quality telepresence meetings can focus on the meeting and the people on the other side of the world without focusing on the technology that's enabling the meeting.

Dynamic Billboards

Yard-scale devices that offer specialized output-only display functionality are commonplace today in transportation centers, retail centers, entertainment venues, and similar locations where people congregate. These devices and software packages are offered by numerous companies, including

Adspace Digital's Mall Network, Appliance Studio's PrintSign, Dynamax's POV system, Haivision's CoolSign, and Sony's Ziris.

Essentially, these systems are dynamic billboards that let their owners update content more readily than a billboard, potentially at the granularity of seconds. Train stations and airports can list departure and arrival times, platforms or gates, and status updates. Shopping malls can display advertisements that change every few seconds. Restaurants can update menus throughout the course of the day. Sporting venues use these displays for scoreboards but can also show instant replays or in-depth coverage of athletes. Although more limited in capability than the yard-scale devices Weiser envisioned, they effectively disseminate information.

Interactive Kiosks

Interactive yard-scale displays are also beginning to appear. Devices, such as the Phex from eKiosk, permit interactive use as well as the more standard information dissemination use discussed earlier. These kiosks are used in airports for ticketing and check-in, in businesses as a virtual receptionist and for wayfinding (including the ability to connect to the host via telephone), and for tourism and in hotels to help visitors find locations and amenities and make reservations independent of time and place.

For example, at Priscilla of Boston Bridal Salons, these displays are used for browsing through selections of gowns and for exploring and configuring options. Customers use the displays directly or with a sales assistant. This is especially helpful with bridesmaids as "bringing in a group of picky gals can wreak havoc on an appointment if they can't agree on the cut and color of their dresses. But the TouchSmart screens let the entire group browse and choose colors, while seeing the transformation take place in front of their eyes."[16] Motorbike and automotive dealers similarly use large interactive displays for demonstrating and selecting different options. These displays represent a blurring of the now almost-ubiquitous digital signage with the functionality of a kiosk.

Assessment: Slower, Specialized Adoption

Yard-scale devices have achieved a slower and more specialized adoption than their inch-scale or foot-scale counterparts, but they have remained close to Weiser's original vision. Retail stores use them as bulletin boards. Schools use them as collaboration tools. Corporations use them as video screens, but currently more for connecting people than for interactive collaboration over content. They achieve these functions while hiding the computers inside—shoppers focus on the purchase, students focus on the educational activity, and meeting participants focus on the discussion.

Yard-scale devices achieve these functions while hiding the computers inside—shoppers focus on the purchase, students focus on the educational activity.

Large touch-screen displays are also appearing in smaller retail environments to provide an "endless aisle"—a way to expand the sales function beyond the physical boundaries of the store or the immediately accessible stock.

As we look to the future, we expect even more yard-scale devices to appear as prices come down and as the hardware becomes rugged enough for deployment in less protected spaces. We expect to see more personalized content appear on large, public displays based upon information available from the inch-scale computers we carry with us. We also expect to see better integration of telepresence functionality with the ability to collaborate over content, all on the same screen, as if the participants were all standing together around the same whiteboard.

Connectivity

Weiser looked forward to a world where many devices were blended into our environment, communicating seamlessly with the environment and each other. To achieve his vision, Weiser described a need for multiple network connections. He foresaw the need for "three different network connections: tiny-range wireless, long-range wireless, and very high-speed wired."[1]

Today, we indeed have multiple network connections for many of our mobile devices. We have cellular, Wi-Fi, Bluetooth, and near-field communication (NFC), providing communication across long distances as well as very short ones.

Cellular communications are a long-range (kilometers) wireless technology that allows mobile transceiver units to communicate with stationary "cell towers." The cell towers are placed across a large geographic area and support mobile transceivers moving across cells during transmissions. Cellular phone service companies commonly provide these networks.

Wi-Fi connections are medium-range (many meters) wireless technology based on the IEEE 802.11 standards (www.wi-fi.org). Wi-Fi networks provide a wireless local area network (WLAN), essentially a wireless alternative to a traditional Ethernet.

Bluetooth connections support short-range (a few meters) wireless communication between two devices, such as mobile phones, headsets, laptops, printers, and handheld game

controllers (http://bluetooth.org). Bluetooth connections require pairing the two devices.

NFC is a tiny-range (a few centimeters) wireless technology that has been standardized to enable easy two-way interactions between electronic devices.[17] By simply touching a device such as a smartphone to a poster or other object with an embedded NFC chip, a user can access content, transfer data, or perform a transaction such as choosing a menu item or making a payment.

In addition, as Weiser predicted, most mobile devices can connect with other computers via a wired cable.

Restaurants and Customer Loyalty

CustomerIn Systems has developed an NFC-based solution called The Connected Restaurant to "reinvent the restaurant dining experience at a time when industry profitability is under siege."[18] The goal is to improve customer service without requiring more work from the restaurant staff, all while speeding up table turnover. Customers entering the restaurant can tap their phones against a poster with an embedded NFC chip, which lets them download the Connected Restaurant application. They can then use this app to check in at the restaurant and ask for a particular table. While waiting, they can read the menu, see customer reviews of menu items, and order. They're alerted when their table is ready, and at the table they can also touch their phones to items on an NFC-enabled menu to get a list of ingredients or a calorie count for a dish. Finally, they can use the app to pay for their meal.

Competing solutions, such as Enable Table, also let diners with NFC-enabled phones pick up and redeem coupons and find information about daily deals, thus increasing customer loyalty.[19] Furthermore, restaurant owners can track service times at particular tables and the popularity of various dishes.

Assessment: Lacking Device Interoperability

Although Weiser correctly predicted today's varied ranges and types of connectivity, current reality in connectivity also differs somewhat from his vision. First, Weiser focused more on the connectivity of devices and less on the connectivity of people that we see today.

Second, Weiser's vision of interconnectedness between these devices and between the devices and their environment has been difficult to achieve. Today, these connections are used mostly for accessing personal productivity applications (such as email, contacts, and calendars), infrastructure providing services and entertainment (such as app stores and social networking sites), and personal communications (such as texting, phone calls, and video conferencing). For example, smartphones are widely used to keep track of incoming email and to communicate with business associates and family alike. They're almost ubiquitously connected to a carrier's or enterprise's infrastructure, but they're not well connected to each other.

We still can't easily move content between our phones, tablets, and boards. Reasons for this are varied. One aspect of the problem revolves around communication: It's challenging to integrate carrier networks and locally owned networks both easily and securely. Other problems include vendor lock-in and incompatibilities between devices sold by different companies. Unfortunately, the missing interconnectedness described in Weiser's article is key to his vision.

Researchers today are actively working to create an "Internet of Things."[20] Until our ability to connect devices with ease and security is moved into commercially available offerings, we won't achieve Weiser's vision of devices cooperating to make people's lives easier.

The reality is that our ubiquitous computing devices are largely disconnected from one another and rarely interoperable.

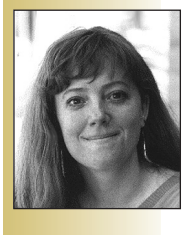
Weiser believed that ubiquitous computing would "gradually emerge as the dominant mode of computer access over the next 20 years."[1] As we review our commercial progress toward Weiser's vision, we see great strides have been made in building the required appliances and infrastructure.

Yet Weiser also described a room where, "depending on [the purpose of] the room, you may see more than 100 tabs, 10 or 20 pads and one or two boards."[1] We have clearly not achieved this scale yet. A technologically-advanced room might have one board and might have as many pads and tabs as there are people in the room—but this is a far cry from Weiser's description. People still very much "own" the mobile devices they use, even if they might share them with family members or students in their classrooms. To achieve this aspect of Weiser's vision, we need to make computers much less expensive, change the way people think about and interact with these devices, and change the way content is made available on the device.

Weiser also pointed out that "the real power of the concept comes not from any one of these devices—it emerges from the interaction of all of them."[1] Although these devices are heavily used to connect people with each other—perhaps more so than Weiser predicted—the reality is that our ubiquitous computing devices are largely disconnected from one another and rarely interoperable.

the AUTHORS

Maria R. Ebling is a research staff member and senior manager at the IBM T.J. Watson Research Center. Her interests are in distributed systems supporting mobile and pervasive computing, privacy, and human-computer interaction. Ebling received her PhD in computer science from Carnegie Mellon University. She serves as an associate editor-in-chief for *IEEE Pervasive Computing*. She was elected to the IBM Academy of Technology in 2011 and is a senior member of both the ACM and IEEE. Contact her at ebling@us.ibm.com.



Mary Baker is a senior research scientist at HP Labs. Her research interests include distributed systems, networks, mobile systems, security, and digital preservation. Baker received her PhD in computer science from UC Berkeley. She is a founding editorial board member of *IEEE Pervasive Computing*. She is a member of IEEE, the ACM, and Usenix. Contact her at mgbaker@hp.com.

We still have a ways to go to achieve the full power of the vision Weiser described. To do so, we need to work more on realizing the "Internet of Things," making the devices easily and naturally interoperable in a secure fashion.

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