Pervasive Computing in Higher Education: A Smart Classroom Model

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Abstract: Advances in mobile devices, Wi-Fi, cellular, and software development have put all the necessary pieces in place for a pervasive computing system to become a reality in the higher education classroom. Studies have shown that cellular phones, iPods, and laptops have the potential to improve the learning experience or improve institutions' communication and reach. Size of software, content capturing, spectrum allocation, and social impact of computers in human-to-human interaction are obstacles for implementation of pervasive computing in the classroom. Standards for pervasive software are needed. The positive educational impacts have been established and the classroom is ready for pervasive computing.

Key Words: Pervasive Computing, Wi-Fi, Higher Education, PDA

1. Introduction: Pervasive Computing and Higher Education

Higher education is facing increased pressure to produce qualified graduates for a future that promises to be dominated by technology not yet developed or imagined. An IBM researcher described this future as:

> "[One]… in which individuals use mobile computers to maintain constant contact with a vast information network that unites everyone into a single community … Given the current technological age, this future may even be the inevitable evolution of society"[1].

The key evolutionary step would be using computers "invisibly." Mitchell Waldrop, writing for Smithsonian, credited Mark Weiser, chief technologist at Xerox Palo Alto Research Center, PARC, for first articulating the principles and ideas of pervasive computing, but he noted that Weiser used the term *ubiquitous computing*[2]. The key concept that Weiser advocated, according to Waldrop, was the inverse of virtual reality, and this was a reality were computers entered "into our world[3]"

The parts of pervasive computing systems in a classroom have been implemented and tested, although in fragmented fashion. The available technology needs to be collected and organized. The following smart classroom scenario presents next fits the concepts of pervasive computing, the current technology, and how obstacles for pervasive computing can be overcome.

2. A Smart Classroom Scenario

The National Institutes of Standards and Technology define pervasive computing as numerous devices that are casually accessed, invisible, embedded in the environment and connected through a ubiquitous network[4].

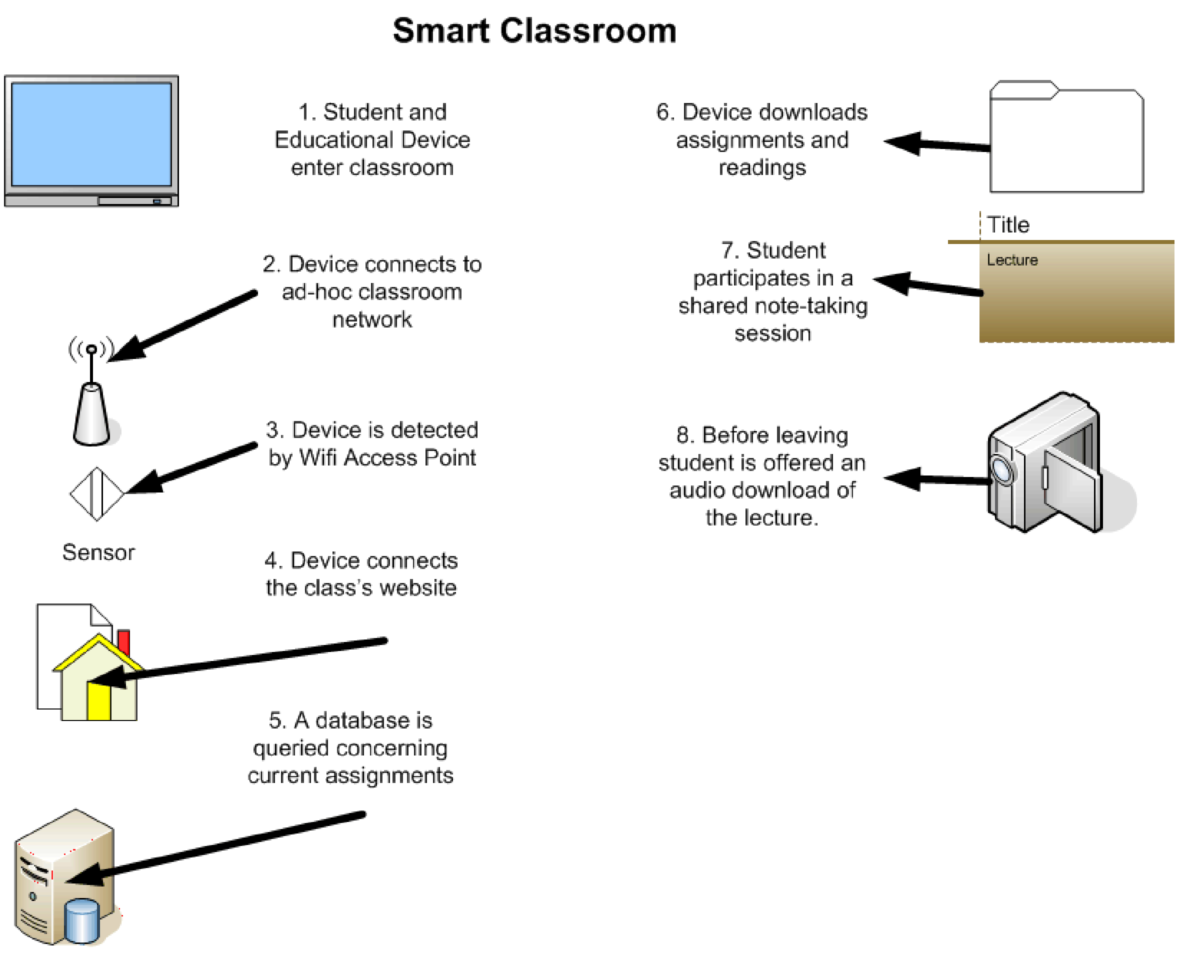

Figure 1: Smart Classroom

The ideal implementation for higher education that meets these requirements would be a Student's Educational Device (SED) interacting with a smart classroom. The SED would be detected when it enters the classroom and would then be offered assignments, textbook chapters, and videos; all would be based on the current assignments of the course. During the class, students could engage in shared note- taking. The connectivity in the classroom would be provided through Wi-Fi. As the student moves from classroom to classroom the process would be repeated based on the class (see Figure 1).

On a bus going home, the SED could take advantage of cellular networking technology and stay updated. The instructor might post an update to a paper that is due and the student would be emailed or text-messaged the change.

The same SED could be used in a smart study area that involves sensors and a personal computer. This smart study area could detect the SED and offer updates and additional information based on classes. The information on the SED could then be uploaded to a personal computer so the assignments could be completed.

2.1 Non-Educational Uses of Pervasive System

Outside the classroom, the SED could provide information depending on the location and services available.

While waiting near a class in progress, information on the class could be displayed. This could be a type of academic advising, allowing the student to see if the course is part of his or her degree program or to preview a limited amount of classroom material or lectures.

The library could push information to the SED based on the student's major. This could include lists of books related to his or her major, and updates on related periodicals in the library.

The SED could also be part of a general communication system. Administration could send reminders about due dates, campus closings, and emergency information.

The core of pervasive computing technology includes wireless networking, mobile SEDs, and mobile software; these technologies are starting to merge perfectly.

3. Pervasive Computing Concepts

The smart classroom would require a merging of wireless networking, mobile devices, and software into pervasive computing. Writing for the Smithsonian, Waldrop described the convergence of these three technologies as:

> "[A] Perfect storm: the convergence of three massive waves of innovation, each driving the other on to new heights. Somewhere in the collision zone we're witnessing the birth of pervasive computing."[3]

This "birth" has already happened in countries around the world. Mobile phone education (m-Education) is being tested in Africa[5]. Mobile phone marketing (m-Commerce) exists in Japan[6].

3.1 Wireless Networking: Wi-Fi and Cellular Merging

It is a mistake to limit the discussion of the SED interacting with the smart classroom and the world through Wi-Fi alone. The discussion should also include cellular technology such as 3G. This would allow access away from the classroom and provide an active calendar, a popular feature in a 1999 test implementation by IBM [7]. The speeds of both types of wireless networking are at broadband speeds[8]. It should also be noted that Wi-fi and cellular technologies are merging. Phones are available that use either Wi-Fi or cellular to place calls or access the internet, and the switching is automatic and seamless to the user[9]. When examining the wireless connection of the computers in our world, we need to consider mobility and quality to determine the best connection for the SED.

3.2 Level of Mobility and Access Quality

The level of mobility and access quality are key when evaluating which wireless networking technology to implement in the pervasive computing smart classroom[8]. The preferred wireless networking technology for pervasive computing is broadband satellites because of the high degree of mobility and access quality (see Figure 2). However, 3G networks would be more practical to implement because of the low cost of access and equipment. Combining 3G or other cellular technology with Wi-Fi presents an even more attractive option for wireless networking. This combination of Wi-fi and cellular technology allows a constant connection for the SED in our world.

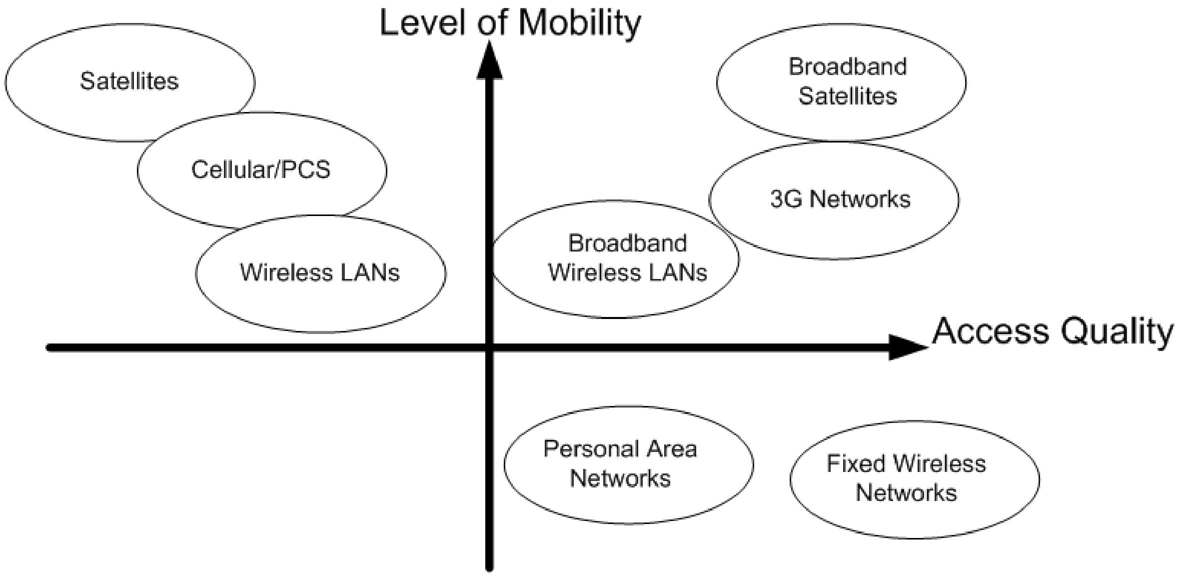

Figure 2. Access and Mobility. Source: Dekleva & Sasha 2007

Mobile SEDs: Smartphones to Laptops

In considering possible SEDs, we must examine each device's capability. These two features have an inverse relationship: as one increases the other decreases.

Candidates for SEDs in the smart classroom include laptops, Smartphones, network-enabled PDAs, web-enabled cell phones, and ultra-mobile PCs. They represent different levels of mobility and capability (see Figure 3).

Desktops have no mobility but can act as a tool for PDAs and other SEDs to synchronize or install software for smaller SEDs.

Laptops that have Wi-Fi and 3G capabilities have good mobility and capability but they lack the easy mobility of a cell phone or a Smartphone. A new system is the ultra-mobile PC (UMPC) with specifications including 7-inch screen, 800 by 400 resolution, and integrated touch screen. It is Wi-Fi enabled, but has no 3G or cellular capabilities currently[10].

Treo Smartphones, the Blackberry, and Apple's iPhone represent typical Smartphones that have the capability to browse the web and send email, but have limited capability for word processing and other applications. PDAs would include Palm or Windows-powered devices that can connect through Wi-Fi or Bluetooth, and PDAs have limited capacities for office-type applications. Web-enabled cell phones are very mobile but offer limited applications.

The preferred SED for mobility would be a Smartphone with rich internet capabilities. This would allow high levels of mobility and enough capability until the phone is synced with a PC. The preferred SED for a blend of mobility and capability would be an ultra-mobile PC, new development in hardware. New Software is also being developed for pervasive computing.

3.3 Mobile Software Development

SED's that are in the world need to be able to understand where they are, find access, find other devices, and know what the student needs to be doing. Waldrop described the functioning of mobile software being able to reach the internet, find resources, and use them as needed "on-the-fly.[3]"

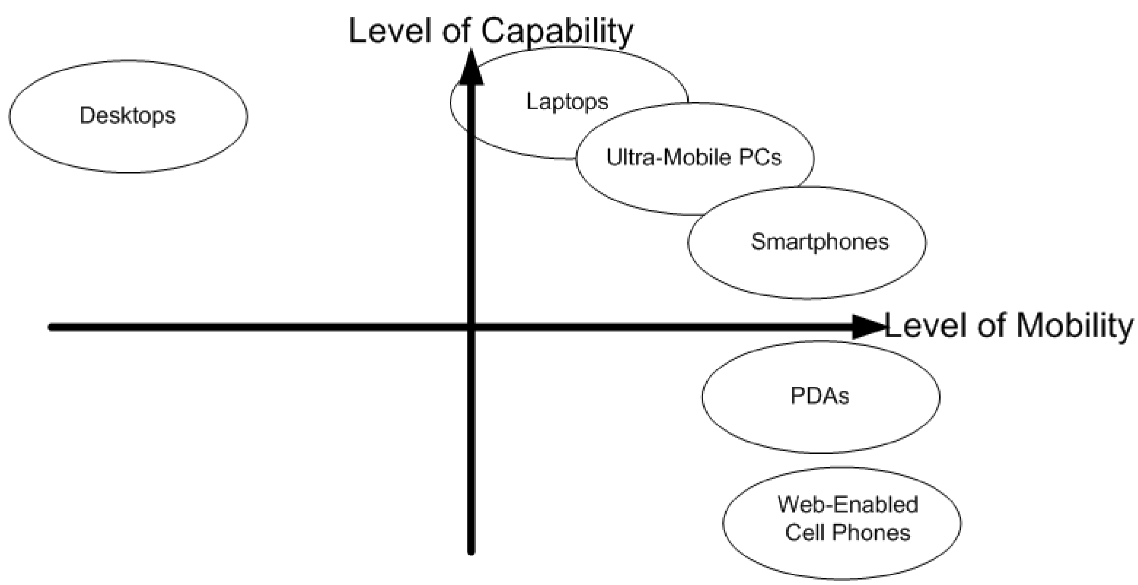

Figure 3: Mobility and Capability of Devices

M-commerce scholars Matthew, Starker, and Varshney framed the "on the fly" software concept as location-based and context-based aware software[6.] The goal of M-Commerce devices is to locate goods and services information that are nearby. For example, they suggest that devices might connect to colleagues' devices during working hours and to family devices on vacation.

M-commerce has been implemented on a limited level in Japan. For example, cell phone users can purchase beverages from Japanese Coca-Cola bottling company machines[7]. These advances show the feasibility of the SED being detected and course specific material being offered when in the classroom.

This "on-the-fly" nature of pervasive software can be built using AURA architecture. This architecture breaks down pervasive software into three main components: Personal Context Observer, Task Manager, and Environment Manager[8].The personal context observer focuses on the user's location, such as the classroom. The task manager would know that the student needs to attend a class or pay tuition by a certain date. The environment manager discovers and connects to networks and computers to complete a task, such as shared note-taking. All of these functions would be vital for the SED in the smart classroom.

4. Technology Advancements for the Smart Classroom

A key component of the smart classroom is an SED, and its basic architecture was laid out in work by IBM researcher, Eustice, as a Universal Information Appliance[9]. The basic requirements of SED would be:

- Platform-specific implementation of a user interface
- Wireless Networking
- Communication Middleware connected to services and information
- Output Mechanism
- Input Mechanism

Eustace reported on a test implementation of a Universal Information Appliance (UIA) using a 1999 vintage Palm Pilot that was a success. He said:

"By having a constant connection to any data desired, the number of mistakes the average person makes in a day will decrease (lost names, lost phone numbers, missed appointments, missed events.[9]"(p. 598).

The Palm device was not named by Eustice but it is assumed that the device was a Palm VII. This Palm had a wireless connection that used Palm.net, an infrared port, a monochrome screen, and 2 megabytes of RAM[13].

Currently, there is a wide selection of devices that exceed the capabilities of the 1998 Palm VII. The iPhone specifications include an 8-gig flash drive, a color screen, Bluetooth, Wi-Fi, cellular connection, and color screen[14]. The ultra-mobile PC, R2H, from ASUS has a 60- gig hard drive, Wi-Fi, color touch screen, and integrated web-camera[15]. The conclusion that can be drawn from the improvement from the Palm VII to the iPhone (and similar devices) is that future implements of a UIA or SED should be more successful and provide more features and capabilities.

4.1 Wireless Mobile Modem to Wireless Broadband

The Palm VII used in the IBM experiment in 1999 used a wireless modem that connected at speeds of 19.2 kbps using the Cellular Digital Packet Standard [16]. Compare this to the download speeds of 400-700 kbps using the Evolution Data Optimized revision a (Ev-Do), which Sprint and Verizon are moving toward in 2007[17]. The speed improvement has been tremendous.

Using the smart classroom scenario and Windows Media server to capture a lecture, it is estimated that a one-hour lecture would create an asp file of 44 Megs[18]. For this 44-meg file, the 1999 palm VII and the 2007 iPhone would have a substantially different download time. Table 1 shows the estimated download time at 80% network efficiency of 4 wireless technologies for the 44-megabyte file. The calculations were made using a tool from Arizona State University[19].

Table 1 Download Time of 1 hour of Lecture (44 meg file)

Technology	Download Time
Palm VII (19.2 kbps)	6 hrs, 40 min, 29.87 sec
Ev-Do revision a (550 kbps)	13 minutes, 58.86 seconds
Wireless 802.11 g (54 mbps)	1.04 seconds
Wired Fast Ethernet (100 mbps)	.56 seconds

The increase in wireless networking speed from 1999 to 2007 makes the implementation of a smart classroom closer to being a reality.

4.2 Software Comparison

The software presented by Eustice used XML, middle, and lightweight database services to provide an active calendar[9]. When an appointment was entered, the software would provide links to the person and company listed in the appointment. This was all text-based.

The main shift in mobile software development has been toward the more natural media of sound and video. This is demonstrated by an implementation of audio-based wiki in Africa. The system involved students' text-messaging a query to a server that would respond with audio content for an Audio-wiki [5]. In addition, the University of Washington is making Podcasts of lectures available[20], and a similar situation is taking place at Harvard[21].

XML, web services, and RSS feeds are playing a part in this rich media content delivery which is an improvement over the text-based software of the Palm VII.

Capture of contents and shared note-taking has also been demonstrated to be feasible. Shared note-taking was studied by IBM and found to "add value to meeting, conference and class records."[22] One of the systems tested was used on a Palm VII and called NotePal. The researcher indicated that NotePal fit easily into the test department's practices.[22] Class content was captured and provided to students as part of a "Classroom 2000 Project" at

Kennesaw State University, northwest of Atlanta. The impact was positive on students' perception of the class, and the benefit-to-cost ratio was favorable[23].Studies in England have shown that students like being informed about campus activities through text messaging on their cell phones [24].

Technology in 2007 is much closer to being able to implement a smart classroom than in 1999. Networking speed, device features, and software have improved. The pieces just need to be engineered into a unified whole.

Despite the successes there are obstacles both from the technology and the people involved. The social impacts of computers being off the desk have been studied but the findings are divided.

5. Obstacles to Implementation

The questions about the impact of pervasive computing on social interaction are an extension of the computer becoming part of our world metaphor. Humans have been shown to assign personality traits to artifacts and machines, so the concern for the impact of SED's in the classroom is legitimate.

Dyer, in IBM Systems Journal, proposed a social computer theoretical model that represented a meshed network with these four traits: system design, human behavior, social attributions, and interaction outcomes[25]. Dyer conducted two experiments and found that a change in the interface design of the receiver influenced the social perception of the sender. Overall, Dyer found the social impact to be negative.

This finding was contradicted by a recent study with Korean middle school students that supported the proposition that Instant Messaging technology enhances personal interaction and relationships[26.]

The question of the social impact of pervasive computing needs to be researched more. Will use of the SED diminish the "social" climate, will students feel more isolated, and will the classroom be viewed as more unfriendly. The answer to these questions will influence the technology design.

5.1 Smaller Software Needed

Most of the software being used in pervasive computing is stripped-down versions of desktop software. True pervasive computing will require "miniature software" for embedded devices and smaller access devices[4]. The development issue is made more complex and difficult by a lack of standards and compatibility inter-operability between current cellular networks[3]. This issue needs to be resolved so pervasive computing can be used throughout society instead of only in isolated pockets.

If pervasive computing does expand, the issue of spectrum allocation has to be addressed. Competing devices might find the wireless space congested and unusable. Waldrop suggested a need for government policy to assist in avoiding the wireless gridlock.

6. Conclusion

There are social, ethical, and technological issues that might hinder the implementation of pervasive computing in a wider society. These issues are less of a concern in a smart classroom; they can be minimized because a campus is a controlled environment. An ultra-mobile PC or a Smart-phone could be used to provide downloads and communication for course management. It is also possible for lectures to be captured by iPod installations.

All the parts are in place for computers to invisibly enter into the classroom to provide a better learning environment. The study on administrators using text messaging, the Harvard Podcast study, and the "Classroom 2000" project all showed favorable outcomes in an educational environment. A smart classroom would be a solid educational investment but the question of social impact still need to be answered.

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