A Pervasive Computing Test Bed

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Introduction

The Internet today is broadband, mobility, and social networking. The Internet of the future will be pervasive, "everyware"[1] access to broadband.[2] With pervasive computing, "all of the information we now look to our phones or Web browsers to provide becomes accessible from just about anywhere, at any time, and is delivered in a manner appropriate to our location and context."[3] This is the coming shift in paradigm for which America should be preparing itself – "an exodus from the PC as a stand-alone platform and a remaking of everyday life around the possibilities of [pervasive] information processing."[4] Moving to a pervasive computing environment is essential to reestablishing American leadership in information technology and thus should be a primary goal of the nation's broadband plan.

To achieve this goal, WCAI recommends that the national broadband plan establish a city-wide pervasive computing test bed. "A key obstacle to research progress in [pervasive] computing is the lack of adequate large-scale experimental infrastructure. . . . The government can act as a catalyst by funding the creation and maintenance of a national test bed for experimental research in [pervasive] computing."[5] A city-wide test bed would spur the development of pervasive computing by providing a locus for collaboration between researchers, industry, and government – all of whom will likely be necessary to evolve our current computing paradigm to a pervasive computing paradigm.

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[1] *See* Adam Greenfield, *Everyware: The Dawning Age of Pervasive Computing* (2006) (coining the term "everyware" in reference to pervasive or pervasive computing).

[2] Pervasive computing is also known as ubiquitous computing, ambient intelligence, or more recently, "everyware." See http://en.wikipedia.org/wiki/Pervasive_computing.

[3] Greenfield, *Everyware*, *supra* note 1, at 1.

[4] *Id*. at 35.

[5] Cynthia A. Patterson, Richard R. Muntz, Cherri M. Pancake, "Challenges in Location-Aware Computing," *IEEE Pervasive Computing*, vol. 2, no. 2, pp. 80-89, 85, April-June, 2003 (available at http://www.computer.org/portal/web/csdl/doi/10.1109/MPRV.2003.1203757).

The benefits of pervasive computing

Pervasive computing turns anything in our environment, including the human body, into a networked resource. Information is being generated everywhere, all the time, but usually without a means of collecting and using it. Pervasive computing enables the collection and use of this data by saturating the environment with computing capability and wireless connectivity. The seamless and unobtrusive collection and dissemination of data in real-time would allow us to easily manage enormous amounts of information that might otherwise have been unobtainable.

A comparison of today's computing model with pervasive computing model demonstrates the stark differences between the two paradigms.

Computing Today	Pervasive Computing
Desktop computing - people typically sit in front of a stationary desktop PC to do their work	*Invisible devices* - numerous, casually accessible, often invisible computing devices
Stationary devices and software - people tend to access computing power in a limited set of locations	*Embedded microchips* - microchip intelligence embedded into everyday devices and objects
Monolithic applications - most applications are designed to interact with humans instead of with other applications	*Ubiquitous network connectivity* - access to information, entertainment, and communication with anyone, anytime, anywhere
Manual mapping - computing tasks are mapped manually to applications (users need to know which application is capable of what)	*Life-enhancing applications* - invisible penetration of technology into the mainstream mass market through a variety of life-enhancing applications
Single device - users typically only use one multi-purpose device at a time	*Consumer-centric* - device "gadgetry" for simple and practical consumer-centric solutions
Manual configuration - users are responsible for configuring applications themselves and keep a single configuration regardless of the environment	*Environment-centric* – devices adapt to their location and the status of their user

As demonstrated by the examples below, the capabilities offered by pervasive computing will be essential to supporting the various purposes envisioned by the national broadband plan, including health care, energy, and education.

- *Healthcare*: Sensors attached to or embedded in the body can provide real-time health information essential to preventative treatment, including heart rate, blood glucose levels, body temperature, and activity levels.[6]
- *Energy*: An "aware home" senses when a person enters or leaves a home or a room and would alter heating, air conditioning, and lighting in response, thus lowering energy use consistently and automatically.[7]
- *Education*: Smart classrooms seamlessly blend e-learning and live classroom techniques into new "p-blended" learning environments.[8]

Challenges of Pervasive Computing

Several challenges must be overcome before the United States can realize the benefits of pervasive computing. Government has an important role to play in overcoming many of these challenges.

- Ubiquitous mobile wireless broadband networks are a prerequisite to evolving America's broadband paradigm to pervasive computing.[9] For all Americans to

[6] *See, e.g.*, http://impact.asu.edu/Ayushman.html (describing a wireless sensor network based health monitoring infrastructure and test bed at Arizona State University).

[7] *See, e.g.*, http://awarehome.imtc.gatech.edu/ (describing Georgia Tech's aware home research initiative).

[8] See Suo, Y. and Shi, Y. 2008, "Towards Blended Learning Environment Based on Pervasive Computing Technologies," in *Proceedings of the 1st international Conference on Hybrid Learning and Education* (Hong Kong, China, August 13 - 15, 2008) (available at http://portal.acm.org/citation.cfm?id=1429761).

[9] See Greenfield, *Everyware*, *supra* note 1, at 204.

realize the benefits of pervasive computing, America's universal service policies must ensure that wireless broadband networks are available everywhere.[10]

- America should ensure that pervasive computing technologies do not impair the privacy rights of individuals. Although such privacy rights may be protected through purely voluntary means, privacy is an area in which government involvement in pervasive computing may be necessary.
- A high level of collaboration will be required to develop new technologies and standards for pervasive computing. A government funded test bed, as discussed in more detail below, would help accelerate this collaborative process and ensure that America is a leader in this area rather than a follower.

Other countries are developing large-scale pervasive computing test beds today

As the PEW Internet Life Project recently recognized, many mobile device users are already entering a new era "where 'continual information exchange' is the norm."[11] The pervasive computing paradigm takes this essentially human interaction to the next level, in which computing can be engaged unconsciously, without direct human input.[12] In a pervasive computing environment, information systems are linked and virtually every*thing* is linked to an information system through wireless (and wired) platforms. Computing becomes so distributed throughout the environment that "computers" effectively disappear.[13]

Such pervasive computing is already happening in other countries. India is building

[10] *See* Comments of WCAI, GN Docket No. 09-51 (filed Jun. 8, 2009) at 39-42 (noting that universal service policies must support both fixed (whether wired or wireless) and mobile broadband access in every area where feasible).

[11] John B. Horrigan, *The Mobile Difference*, Pew Internet and American Life Project, at 97 (Mar. 25, 2009) (available at http://www.pewinternet.org/Reports/2009/5-The-Mobile-Difference--Typology.aspx).

[12] Greenfield, *Everyware*, *supra* note 1, at 66.

[13] *Id*. at 1.

a healthcare research grid based on pervasive computing principles,[14] and South Korea is planning to build approximately 15 "pervasive cities."[15] The New Songdo city currently under construction in South Korea is being built as a test bed for pervasive computing technologies and will offer an opportunity to study the large-scale use of radio-frequency identification, smart cards, and sensor-based devices.[16] "Imagine public recycling bins that use radio-frequency identification technology to credit recyclers every time they toss in a bottle" or using the same key to ride the subway, pay a parking meter, and see a movie.[17] That is the promise of pervasive computing that Korea is working to realize today.

The United States risks falling behind in the coming shift to a pervasive computing paradigm

While there have been extraordinary levels of private investment in broadband networks in the United States, the United States nevertheless lags in the development of pervasive computing test beds similar to those discussed above. There are no plans for "pervasive cities" here. Indeed, the inevitable shift to a pervasive computing paradigm has largely gone unnoticed in the broadband policy debate.[18] This must change if America is to be at the forefront of the next computing revolution. We should not focus merely on building a faster and more universally deployed version of the largely static broadband infrastructure that predominates today. Instead, the National Broadband Plan should

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[14] See http://discovery.bits-pilani.ac.in/rahul/PervasiveComputing/SSZG531-Introduction-to-Communication-Technologies.pdf.

[15] See http://en.wikipedia.org/wiki/Pervasive_city.

[16] Pamela Licalzi O'Connell, *Korea's High-Tech Utopia, Where Everything Is Observed*, New York Times (Oct. 5, 2005) (available at http://www.nytimes.com/2005/10/05/technology/techspecial/05oconnell.html?ex=1286164800&en=4a368c49e8f30bd2&ei=5088).

[17] *Id*.

[18] The lack of a national policy discussion of pervasive computing may lead to local regulation that impedes progress. See http://future.iftf.org/pervasive_computing/.

accelerate our transition to the pervasive computing paradigm.[19] Anything less would have us playing a perpetual game of "catch up" with other nations.

Establishing a pervasive computing test bed would help ensure that the United States is a leader in pervasive computing

To avoid this possibility, the National Broadband Plan should establish a city-wide pervasive computing test bed. The test bed would provide industry, public institutions, and the government with an opportunity to address many of the challenges of pervasive computing in a collaborative environment that would provide practical experience with pervasive computing networks on a large scale. A test bed designed to achieve specific goals would provide a model for accelerating the computing paradigm shift in the United States and enable the U.S. to maintain global leadership in communications technology. Such goals would include:

- Developing technologies and standards necessary to support pervasive computing;
- Promoting the adoption of pervasive computing technologies and standards by the private business sector, the general public, and throughout public institutions like health, public safety, and education; and
- Establishing information sharing policies that protect consumer privacy without sacrificing functionality.

The test bed would also yield significant data on other issues that would inform the continuing evolution of the national broadband plan, including factors that affect consumer broadband adoption and the impact of broadband coordination at all levels of government, public institutions, and industry.

To be effective, a pervasive computing test bed should be federally funded using an RFP process. RFP processes should be used to select all participants, including the

[19] See http://en.wikipedia.org/wiki/Pervasive_city.

community and public institutions, network operators, vendors, and software developers. The ideal community would demonstrate a strong commitment to pervasive computing and a CIO capable of coordinating such a system across multiple public institutions. Interconnected wireless and wireline networks would be required, which could be supplied by one or more operators committed to collaboration and capable of supporting simultaneous tests of a wide variety of new technologies. Finally, the RFP process should be open to hardware and software vendors for the development of new equipment with pervasive computing functionality.

Although pervasive computing can use existing networks and spectrum, a pervasive computing test bed could be combined with existing or new spectrum technology test beds. For example, pervasive computing could be tested alongside spectrum sharing technologies intended for use with the existing joint FCC-NTIA spectrum test bed.[20] Pervasive computing could also be tested along with other new spectrum technologies in the 40-42 GHz V-Band spectrum, a band suggested for use as a new technology test bed by Sprint Nextel,[21] or in other lightly-used bands. High frequency bands like the V-Band may be especially useful for short-range sensors and other pervasive computing devices used at the scale of the body or the room.

Conclusion

As WCAI noted in its initial comments in this proceeding, pervasive computing capabilities have been largely unrepresented in the broadband policy debate. This should change if the United States is to be at the forefront of broadband and computing. Developing

[20] *See Fostering Innovation and Investment in the Wireless Marketplace*, NOI, FCC 09-66 (rel. Aug. 27, 2009) at ¶ 30 n. 23 (citation omitted).

[21] *See* Comments of Sprint Nextel Corporation – NBP Public Notice #6, GN Docket Nos. 09-47, 09-51, and 09-137 (filed Oct. 23, 2009) at 27-28.

a large-scale pervasive computing test bed would help ensure that the United States accomplishes those goals.

Respectfully submitted,

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