Abstract

In the twenty-first century the technology revolution will move into the everyday, the small and the invisible. The impact of technology will increase ten-fold as it is imbedded in the fabric of everyday life. As technology becomes more imbedded and invisible, it calms our lives by removing annoyances while keeping us connected with what is truly important. This imbedding, this invisibility, this radical ease-of-use requires radical innovations in our connectivity infrastructure. This article describes the interplay and dependencies between invisibly calming technology and the new pervasive connectivity infrastructure.

Calm Technology and Pervasive Connectivity

Mark D. Weiser

Remembering Mark Weiser: Chief Technologist, Xerox PARC

Roy Want

Mark Weiser was a remarkable man. He had genius, vision and he loved people. A discussion with Mark was always enjoyable, and whoever he talked to, he made feel like an equal.

At Xerox PARC, I had the pleasure of working with Mark for 8 years. He was largely the reason I joined PARC and, during this time, I continued to be impressed by his ideas and the breadth of his technical skill. Sadly, as many of you already know, he became ill in March '99 and his condition was quickly determined to be the work of cancer. Even at that point, neither Mark nor any of his colleagues realized we would have just 7 more weeks before this chapter would come to an end. When Mark died on April 27th 1999 at his home in Palo Alto, he was only 46 and far too young for such a tragedy. The abstract above was one of his last pieces of writing and intended as a placeholder for a paper to be published in IEEE-PCS, which as it turned out, he would never write.

Mark was a visionary and best known for the research program he created at Xerox PARC in 1988, called Ubiquitous Computing. Ubicomp, the name it was often shortened to, included many fields of computer science such as mobile computing, distributed systems, user-interface design and low-power design. However, it was more than just a collection of disciplines, it was also a philosophy with two key ideas. First, the notion of invisible computing, one in which computers fade into the background of our work environment. This is a

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world in which computation becomes implicit with the work at hand. The second idea is one of computing that engenders calmness. Computers for many of us focus our attention and often lead to frustration. Mostly they exasperate us with complex and esoteric user interfaces. Failures are often difficult to diagnose, and if networks are involved, performance is variable. Mark's vision of the future predicted computers embedded in everyday objects enhancing their purpose. Ubiquitous computing would allow us to leverage the natural associations of the physical world with all the advantages and power of modern day electronic storage and computation.

In order to achieve this vision Mark realized early on that pervasive connectivity was the key to orchestrating the myriad of computers in this future world. He wrote a seminal article for Scientific American "The Computer for the Twenty-First Century," Vol. 265, No. 3, (September 1991), pp. 94-104 which described how devices of various sizes and functionality could work together using both wireless and infrared networks to achieve this aim. A quote from Randy Katz, "This [paper] is required reading for anybody entering the field." There were many other papers to follow, some of which are listed at the end of this article. These were not just ideas. At Xerox PARC members of his team designed, prototyped and deployed many of the systems he described, demonstrating their utility. To a large extent these systems were bound by the technology of the early 1990's and not ready for commer-

cialization. As technology marches on, the world is becoming ripe for this new way of working and in the twenty-first century we will see many of Mark's ideas instantiated in an ever-growing embedded computation market. His legacy to Xerox will be a treasure chest of intellectual property that will touch many of these future systems.

As with other visionaries, it takes time for their novel ideas to take hold. It is only recently that his work has received the endorsement it deserved. In the beginning of this year, and before he had become ill, many of his esteemed colleagues, including Randy Katz (Berkeley), Leonard Kleinrock (UCLA) and Dave Johnson (CMU) nominated him for the 1999 ACM SIGMOBILE award for "Outstanding contributions to the field of mobile computing." Before Mark died, I had been able to tell him that he was the recipient of this year's award. Although very weak he smiled and gave me a long hug – it clearly meant a great deal to him. In his absence, his eldest daughter, Nicole, received the award at the Mobicom '99 conference held in Seattle, August 17th.

In addition to Ubiquitous Computing, Mark had many other research interests that included garbage collection, operating systems and user interface design. He held several U.S. and foreign patents, and wrote or co-wrote more than 75 technical publications on subjects such as the psychology of programming, program slicing, operating systems, programming environments, garbage collection and technological ethics. He had been a member of the Computer Science Department at the University of Maryland between 1979 and 1987 and in the latter years had become a tenured professor. During that time he taught graduate and undergraduate courses on human factors, systems, and programming. He was a popular speaker at scientific symposia and conferences, and a frequent subject of media interviews.

He was also known for his music. Mark played the drums and regularly performed with his friends in an avant-garde rock band called, "Severe Tire Damage" which gained notoriety when it became the first band to play live on the Internet. The band made this digital debut by broadcasting over the Internet just before the Rolling Stones were about to play, effectively their opening band. Later Severe Tire Damage made a CD that became well distributed in Silicon Valley.

Mark was born on July 23rd, 1952 in Chicago, Illinois and grew up in Stony Brook N.Y. He was married with two children. During his career he founded three companies, defined a new field of research and inspired a new generation of researchers. I will remember him for his tremendous energy and enthusiasm, his delightful humor, infectious laughter and expansive thinking. He was both a friend and a mentor to me, somebody whose loss will impact my work on a daily basis.

The following are highlights of his career accomplishments. For more details, please see http://www.ubiq.com/weiser/.

Accomplishments

1999: Recipient of the Association for Computing Machinery (ACM) SIGMOBILE award, in recognition of his outstanding contributions to mobile computing

1996–1999: Chief Technology Officer, Xerox PARC

Dec. 1995: Program Chair for the Association for Computing Machinery (ACM) Fifteenth Symposium on Operating System Principles

June 1993: Severe Tire Damage became the first band to broadcast live video and audio worldwide on the Internet.

1993: ACM & IEEE, International Conference on Software Engineering "Best Paper Ten Years Later" award for "Program Slicing."

1992–1994: Associate Editor of Transactions on Software Engineering

1992–1994: Elected to board of the Computer Research Association. Founder of the CRA series of annual conferences for heads of industrial computer science research laboratories.

Sept. 1991: Seminal article, The Computer of the 21st Century, appeared in "Scientific American" magazine. It remains essential reading for people entering the field.

1988–1995: Manager of the Computer Science Laboratory, Xerox PARC

1988: Became Principal Scientist, Xerox PARC

1987: Joined Xerox PARC as Member of Research Staff

1979–1987: C.S. Dept., University of Maryland (Associate Chairman, (1986–1987)

1979: Received Ph.D. from University of Michigan, Computer and Communication Sciences

1976: Received M.S. from University of Michigan, Computer and Communication Sciences

1973–1976: Co–founder and President, Cerberus Inc., Ann Arbor, MI

Other Activities

Principal Investigator on grants and contracts with ARPA, AFOSR, NSF, and NASA.

Professional Societies: Association for Computing Machinery, IEEE Computer Society, AAAS.

Reviewer of papers and proposals for International Conference on Software Engineering, IEEE, Transactions on Software Engineering, Journal of Systems and Software, National Science Foundation, Communications of the ACM, Software–Practice & Experience, Acta Informatica, IEEE Software, and others.

Public Software: PCR – AutoTetris – game for Sun workstations, 1992; Portable Common Runtime system providing threads, garbage collection, I/O and symbol table manage-

ment for multiple languages and operating systems, 1989; SDI – game for Sun workstations, 1987.

Selected Publications

D. Russell and M. Weiser, "The Future of Integrated Design of Ubiquitous Computing in Combined Real and Virtual Worlds," *Proc. CHI '98*, Los Angeles, CA, 1998, pp. 275–76.

M. Weiser and J. Seely Brown, "Center and Periphery: Balancing the Bias of Digital Technology," *Blueprint for the Digital Economy*, Edited by Don Tapscott, McGraw–Hill, 1998, pp. 317–35.

M. Weiser and J. Seely Brown, "Riding on a Sea of Calm," *World Link*, Jan./Feb. 1998, pp. 48–50

M. Weiser and J. Seely Brown, "Designing Calm Technology," PowerGrid Journal, vol. 1.01, http://powergrid.electriciti.com , July 1996. Also appeared as Chaper 6 – "The Coming Age of Calm Technogy" in the book "Beyond Calculation – The Next Fifty Years of Computing" by P. J. Denning and R. M. Metcalfe, Copernicus/An Imprint of Springer-Verlag.

M.Weiser, "Open House," Review, the web magazine of the Interactive *Telecommunications Program of New York University*, Mar. 1996,

R. Want, B. Schilit, N. Adams, R. Gold, D. Goldberg, K. Petersen, J. Ellis, and M. Weiser, "An Overview of the Parctab Ubiquitous Computing Experiment," *IEEE Pers. Commun.*, Dec. 1995, vol. 2. no. 6, pp. 28–43.

M. Weiser and A. Garman, "Bleeding Edge Technology – From Lab Coats to Market Caps," *Red Herring*, Aug. 1995

M. Weiser, "The Technologist's Responsibilities and Social Change," *Computer–Mediated Communication Mag.*, V2N4, Apr. 1, 1995

M. Weiser, A. Demers, B. Welch, and S. Shenker, "Scheduling for Reduced CPU Energy," *Operating System Design and Implementation (OSDI) Conf.*, Monterey, CA, Nov., 1994.

V. Reich and M. Weiser, "Libraries are More than Information: Situational Aspects of Electronic Libraries," *CSL Technical Report 93–21*, June 1994. also Serials Review, 1994, V20N3, pp. 31–38.

M. Weiser, "The World is not a Desktop," *Interactions*, Jan. 1994, pp. 7–8.

C. A. Kantarjiev, A. Demers, R. Frederick, R. T. Krivacic, and M. Weiser, "Experiences with X in a Wireless Environment," *Proc. USENIX Symposium on Mobile & Location–Independent Computing*, Aug. 1993.

M. Weiser, "Some Computer Science Problems in Ubiquitous Computing," *Communications of the ACM*, July 1993, (reprinted as "Ubiquitous Computing," Nikkei Electronics; Dec. 6, 1993).

M. Weiser, "The Computer for the Twenty–First Century," *Scientific American*, Sept. 1991

M. Weiser, A. Demers, and C. Hauser, "The Portable Common Runtime Approach to Interoperability," *ACM Symp. Operating Systems Principles*, Dec. 1989.

H. Boehm and M. Weiser. "Garbage Collection in an Uncooperative Environment," *Software: Practice and Experience*, Sept. 1988

G. Pearson and M. Weiser, "Exploratory Evaluations of Two Versions of a Foot–Operated Cursor–Positioning Device in a Target Selection Task," *Conf. Human Factors in Computing Systems '88*, May 1988.

J. Callahan, D. Hopkins, M. Weiser, and B. Shneiderman. "Experiments with Pie Menus," *Conf. Human Factors in Computing Systems '88*, May 1988

M. Weiser, "Program slicing," *IEEE Trans. Software Engineering*, vol. SE–10, no. 4, July 1984.

M. Weiser and C. Torek, "The Maryland Window System," *Proc. 1984 Unix Users (Usenix) Conf.*, Salt Lake City, Utah, June, 1984, pp. 166–72.