

Sources of inspiration in mobile computing

Lin Zhong's personal story with MobiSys



My first research topic: High-level synthesis

- Take behavior description of a circuit in a high-level language (like C)
- Output architectural description in a hardware description language (like VHDL)
- Design would be simulated by a tool for speed, area, and power
- Not actually implemented in hardware; never saw a chip
- Not very satisfying to me

High-Level Synthesis: Current Status and Future Directions

Gaetano Borriello

Department of Computer Science, FR-35
University of Washington
Seattle, WA 98195

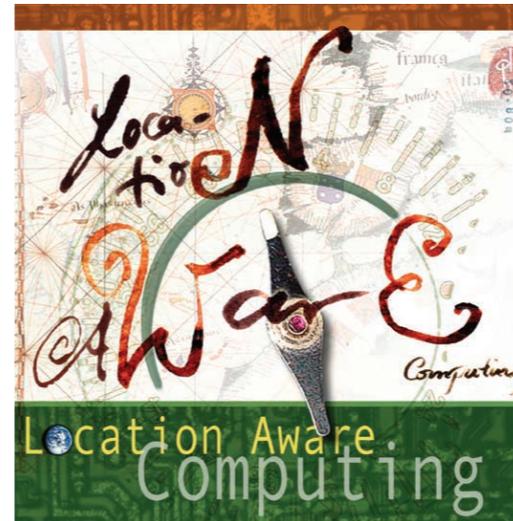
Ewald Detjens

Exemplar Logic, Inc.
Berkeley, CA 94703

ACM Design Automation Conference (DAC) 1988



Location Systems for Ubiquitous Computing



This survey and taxonomy of location systems for mobile-computing applications describes a spectrum of current products and explores the latest research in the field.

Jeffrey Hightower

Gaetano Borriello
University of Washington

To serve us well, emerging mobile computing applications will need to know the physical location of things so that they can record them and report them to us: What lab bench was I standing by when I prepared these tissue samples? How should our search-and-rescue team move to quickly locate all the avalanche victims? Can

onal, nor equally applicable to every system, the classification axes we present do form a reasonable approach to characterizing or evaluating location systems.

The Global Positioning System is perhaps the most widely publicized location-sensing system. GPS provides an excellent lateration framework for determining geographic positions. The worldwide satellite

IEEE Computer, August 2001

Gaetano the high-level synthesis pioneer doing ubiquitous computing





Margaret the renowned microarchitect doing Zebranet (circa 2002)

Talked my advisor into buying this

Spring 2003



Sharp Zaurus SL5600 (2002), embedded Linux/embedded Qt

Quantifying the Energy Consumption of a Pocket Computer and a Java Virtual Machine

Keith I. Farkas Jason Flinn* Godmar Back* Dirk Grunwald* Jennifer M. Anderson*
Western Research Lab, Compaq Computer Corporation
250 University Ave., Palo Alto, CA. 94301 U.S.A.
keith.farkas@compaq.com

SIGMETRICS 2000



Figure 1: The Itsy Pocket Computer Version 1.5

Energy Estimation Tools for the *Palm*TM

Todd L. Cignetti, Kirill Komarov, and Carla Schlatter Ellis

Department of Computer Science
Duke University
Durham, NC 27708 USA
{cignetti,kirill,carla}@cs.duke.edu

MSWiM 2000



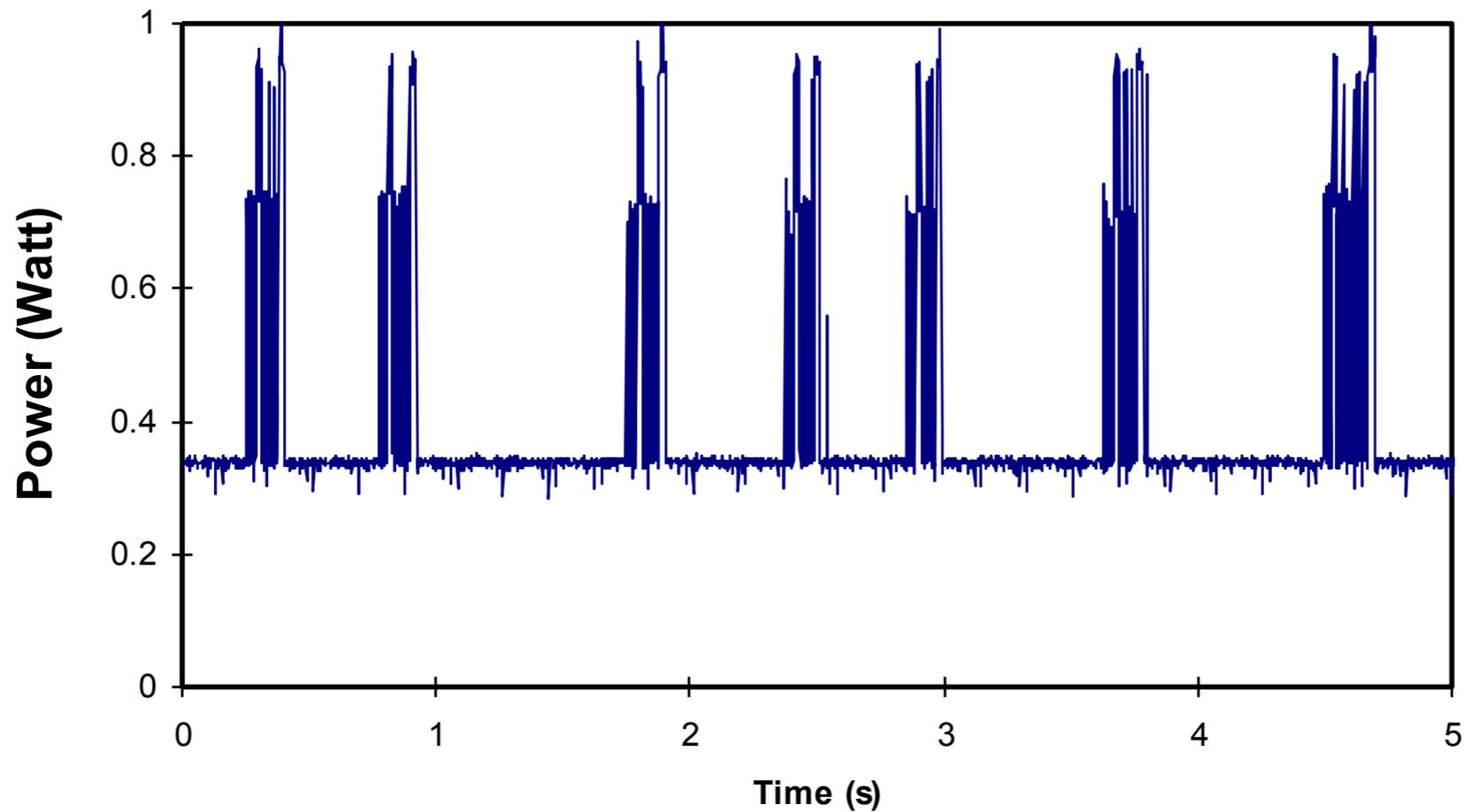
Dirk Grunwald and Carlar Ellis later served as general-co-Chair and PC co-Chair of MobiSys 2008, respectively

My (naive) epiphany: most of the code is for graphical user interface



It was difficult for me to comprehend the code but I could count the lines

How does graphical user interface matter for energy efficiency?



Using Calculator on Sharp Zaurus PDA

Graphical User Interface Energy Characterization for Handheld Computers*

Lin Zhong and Niraj K. Jha
Department of Electrical Engineering
Princeton University
Princeton, NJ 08544
{lzhong, jha}@ee.princeton.edu

Proc. Int. Conf. on Compilers, Architectures & Synthesis for Embedded Systems (CASES) October 2003

MobiSys2003

THE FIRST INTERNATIONAL CONFERENCE ON
MOBILE SYSTEMS, APPLICATIONS, AND SERVICES

SAN FRANCISCO, CA, USA MAY 5-8, 2003

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THE USENIX ASSOCIATION, IN COOPERATION WITH ACM SIGOPS

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The first MobiSys already happened but I had no clue

Quantifying the Energy Consumption of a Pocket Computer and a Java Virtual Machine

Keith I. Farkas Jason Flinn* Godmar Back* Dirk Grunwald* Jennifer M. Anderson*
Western Research Lab, Compaq Computer Corporation
250 University Ave., Palo Alto, CA. 94301 U.S.A.
keith.farkas@compaq.com

SIGMETRICS 2000



Figure 1: The Itsy Pocket Computer Version 1.5

In the process of writing the CASES paper, I checked out Jason Flinn

Odyssey

17th ACM Symposium on Operating Systems Principles (SO SP '99),

Published as *Operating Systems Review*, **34**(5):48–63, Dec. 1999

Energy-aware adaptation for mobile applications

Jason Flinn and M. Satyanarayanan
School of Computer Science
Carnegie Mellon University





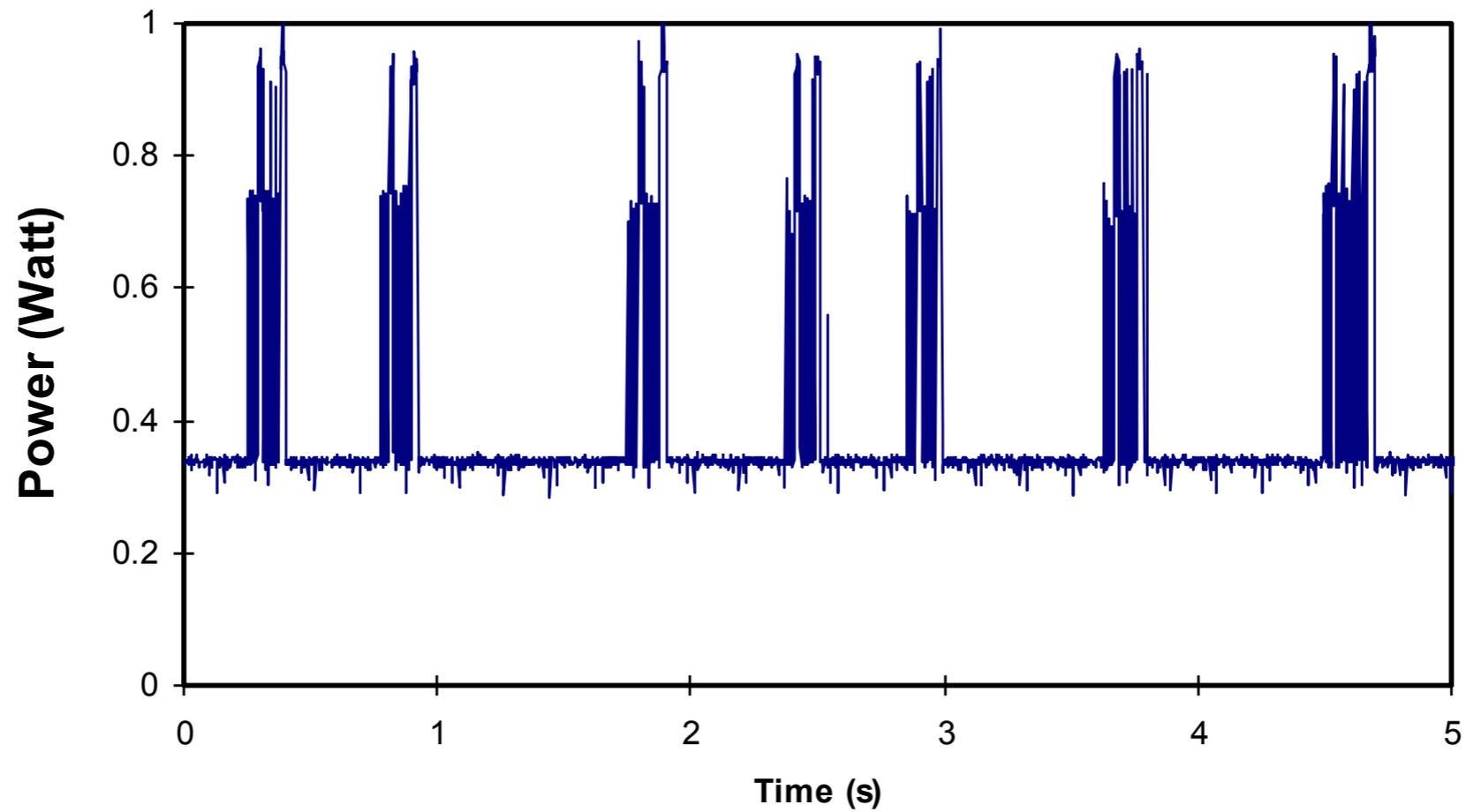
The beauty and awe of a solid system work. It reaffirmed my interest in mobile systems: it was much more interesting to me than the papers about high-level synthesis, despite that I did not understand much of it.



<http://www.panoramio.com/photo/12982144>

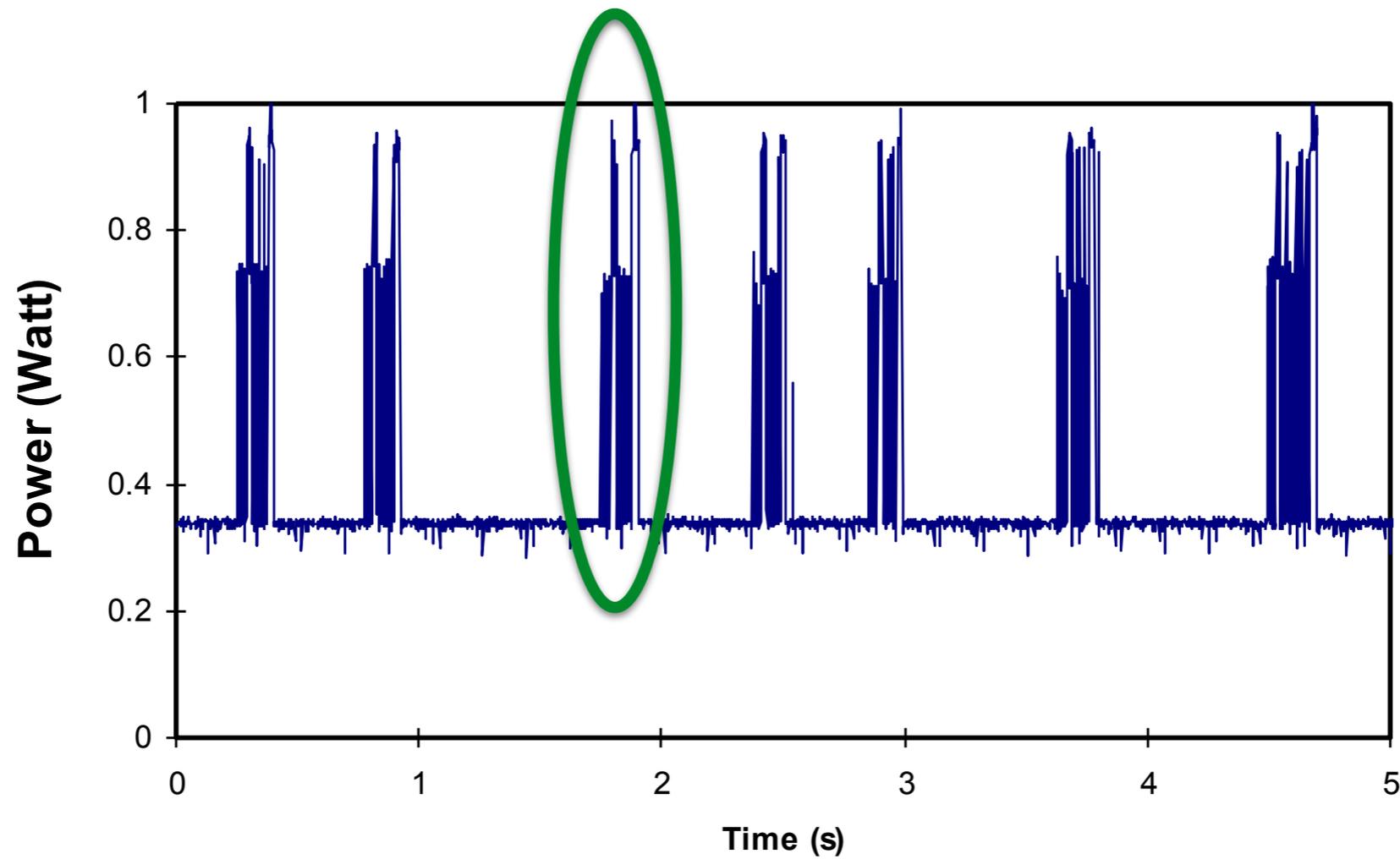
How I felt about my own paper in comparison

How does graphical user interface matter for energy efficiency?



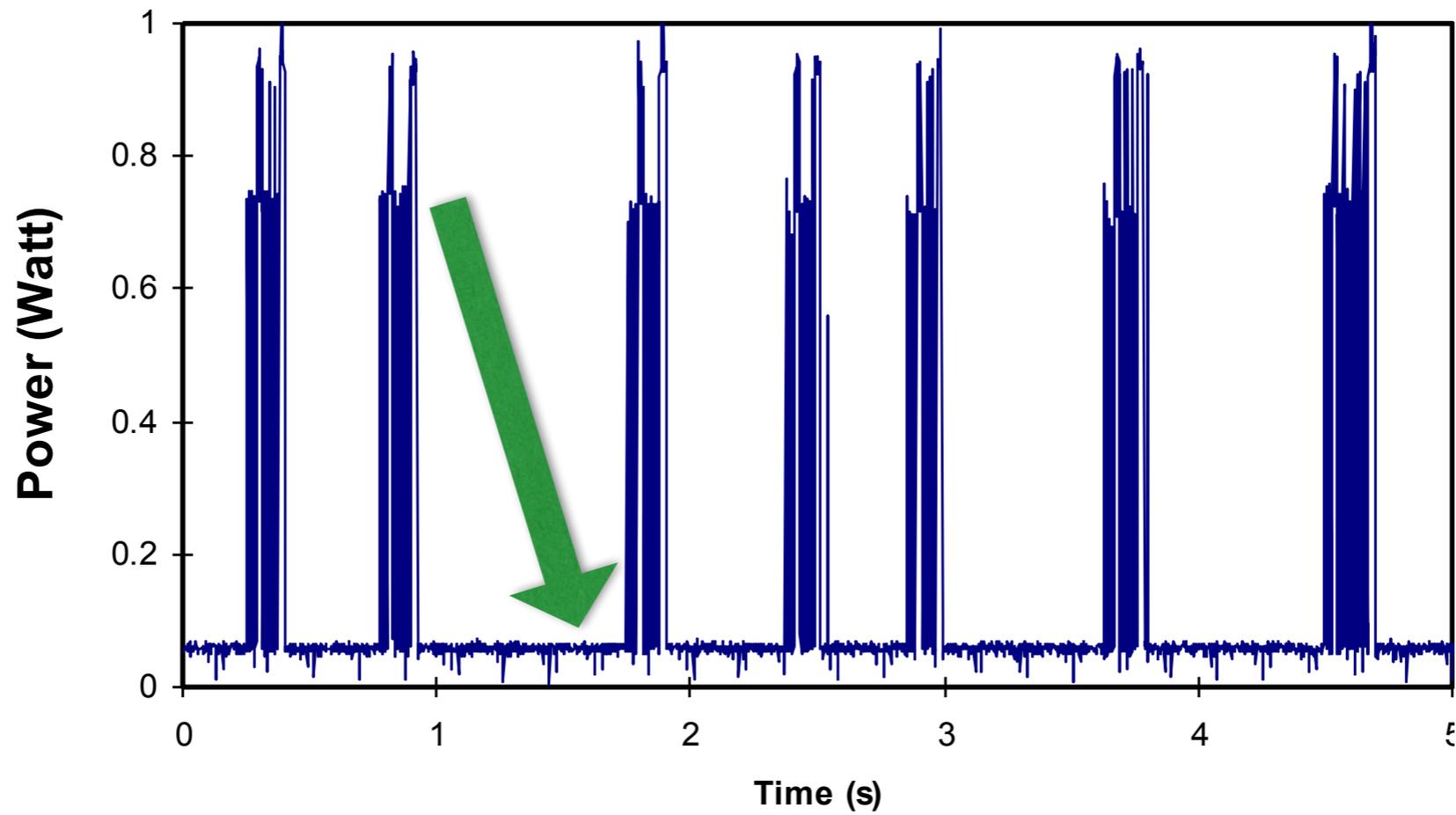
Using Calculator on Sharp Zaurus PDA

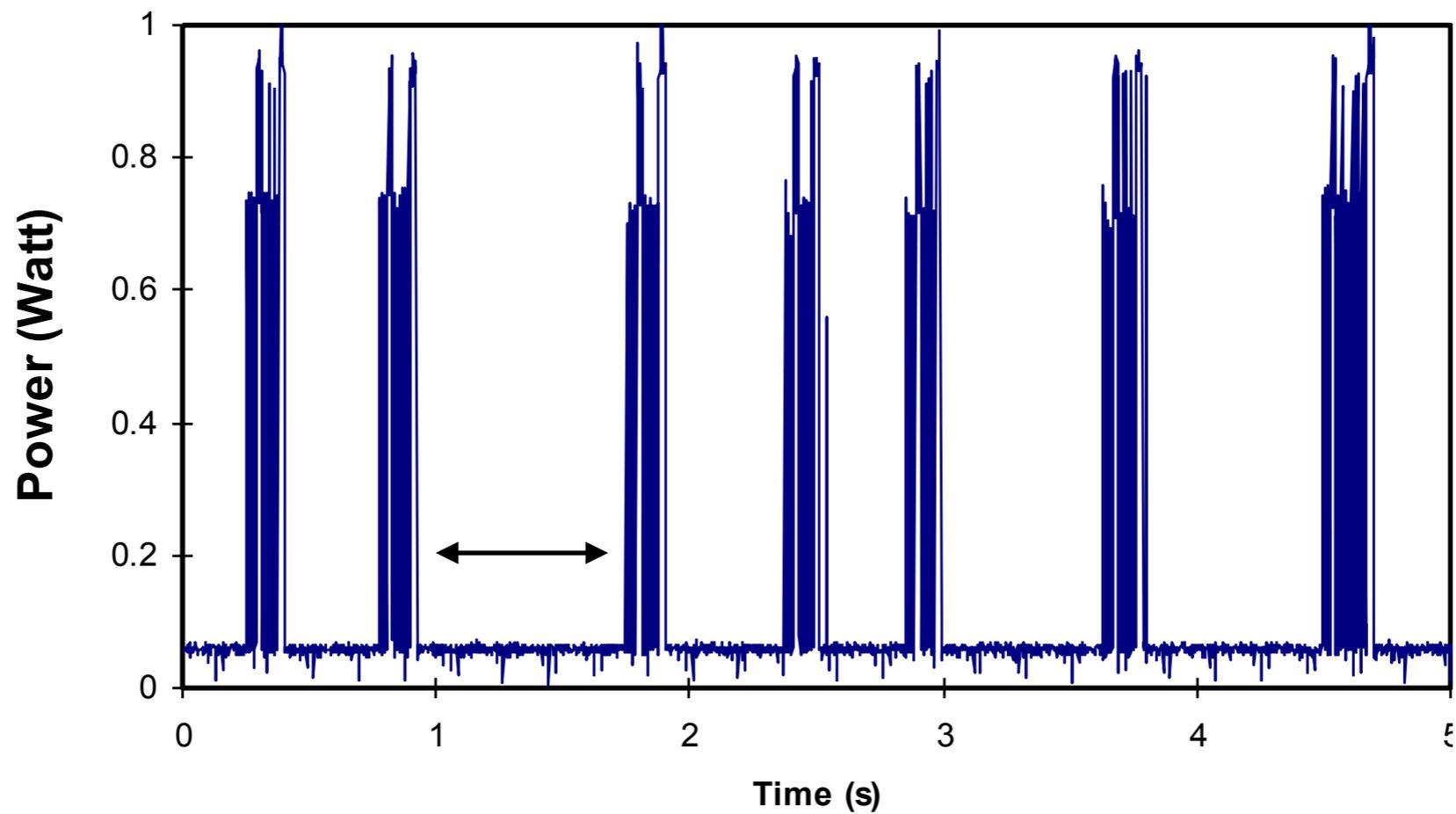
99% time and 95% energy spent waiting during interaction



Using Calculator on Sharp Zaurus PDA

Epiphany: the most effective way is to reduce the idle power consumption





Predict user delay using (1) history and (2) **psychology**

Dynamic Power Optimization of Interactive Systems

Lin Zhong and Niraj K. Jha
Department of Electrical Engineering
Princeton University
Princeton, NJ 08544
{lzhong, jha}@ee.princeton.edu

IEEE Int. Conf. VLSI Design, January 2004

A clever, interdisciplinary idea but partial implementation

Got started with human psychology

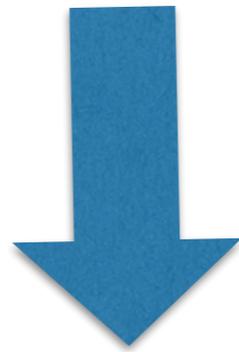
“User attention is the most precious computing resource”

- April 8, 2004, 4:30 p.m., Princeton Electrical Engineering seminar "Pervasive and Context Aware Computing" by **Daniel Siewiorek**
- Project Aura
 - Distraction-free Ubiquitous Computing

<http://www.cs.cmu.edu/~./aura/auravideo.mpg>



“User attention
is the most precious computing resource”



It is the human user that limits the
energy efficiency of computers

$$\text{Energy efficiency} = \frac{\text{User productivity}}{\text{Average power consumption}}$$

How I discovered MobiSys

circa June 2004

Following up Jason's work led to
my discovery of MobiSys

**Ghosts in the Machine:
Interfaces for Better Power Management**

Manish Anand, Edmund B. Nightingale, and Jason Flinn
Department of Electrical Engineering and Computer Science
University of Michigan

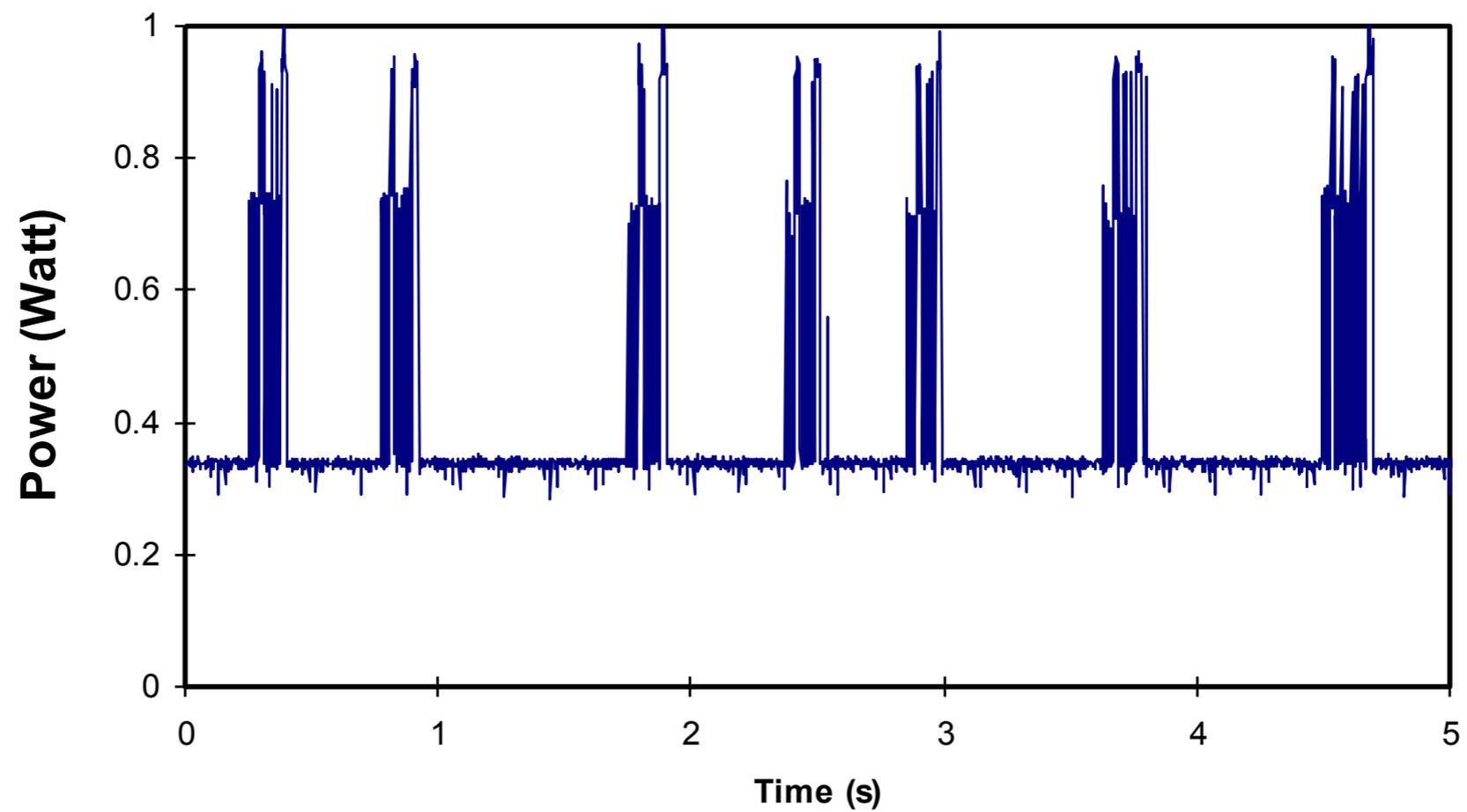
Best Paper from MobiSys 2004

μ Sleep: A Technique for Reducing Energy Consumption in Handheld Devices

Lawrence S. Brakmo

Deborah A. Wallach

Marc A. Viredaz

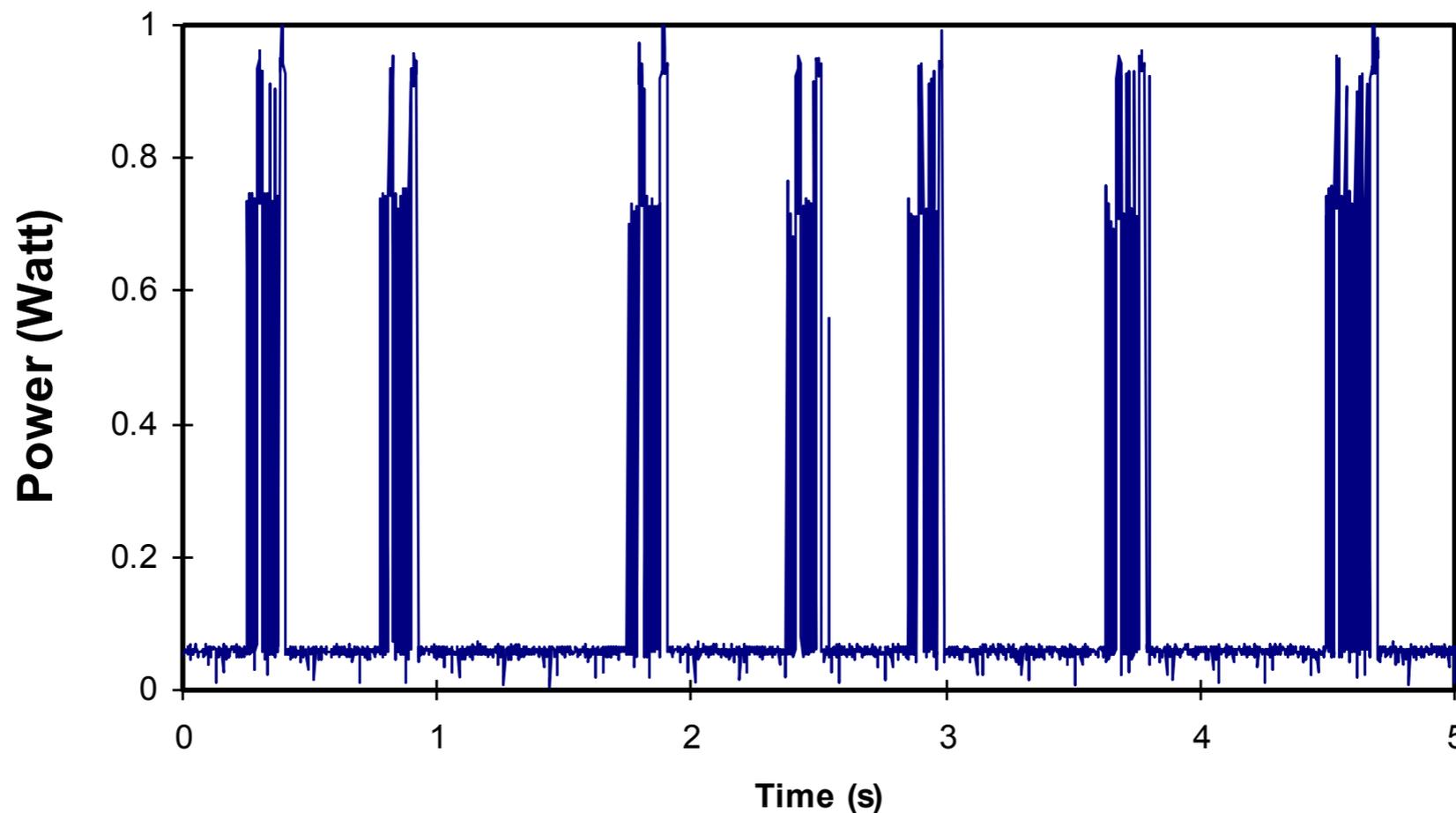


μ Sleep: A Technique for Reducing Energy Consumption in Handheld Devices

Lawrence S. Brakmo

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Marc A. Viredaz



This paper did what I was not able to do in the VLSI Design paper: it implemented the power management in the Linux operating system; and the short wakeup time almost made my solution irrelevant. (1) I felt lucky that the VLSI design paper appeared half year before; and (2) I felt that there is a lot things to learn about building systems



<http://tropicalsails.com/spring-2014-yunnan-china-ethnic-discovery-tours/>

How I felt about uSleep



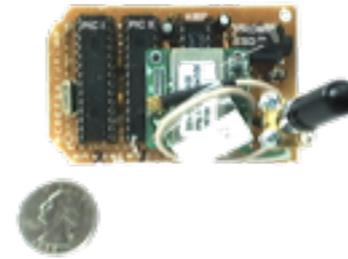
How I felt about my own paper in comparison

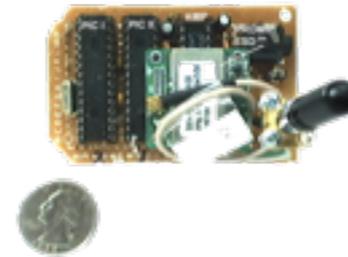
I did not know how to build systems!!!!

How I learned about building things

- Internship at MSR Redmond
- Hardware Devices Group
 - Mike Sinclair and Turner Whitted
- Project WITTY
 - Using bone-conduction microphone to de-noise







**A Personal-Area Network of Low-power Wireless
Interfacing Devices for Handhelds:
System & Hardware Design**

Lin Zhong*
Dept. of ECE
Rice University
Houston, TX 77251
lzhong@princeton.edu

Mike Sinclair
Hardware Devices Group
Microsoft Research
Redmond, WA 98052
sinclair@microsoft.com

Niraj K. Jha†
Dept. of Electrical Engineering
Princeton University
Princeton, NJ 08544
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Short paper at ACM MobileHCI 2005

Back Princeton: Time to try MobiSys!

It is the human user that limits the energy efficiency of computers

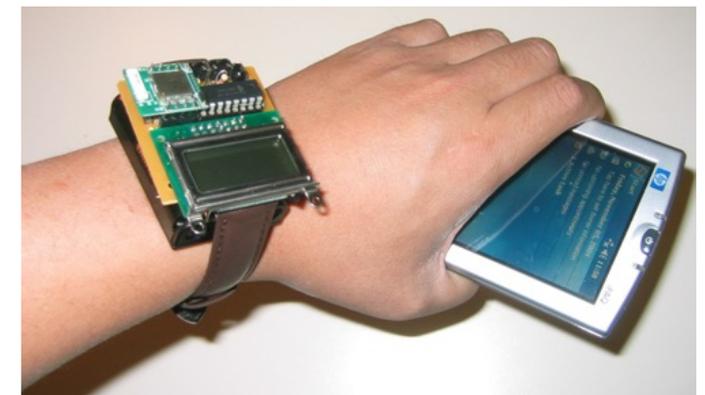


Submitted to MobiSys'05

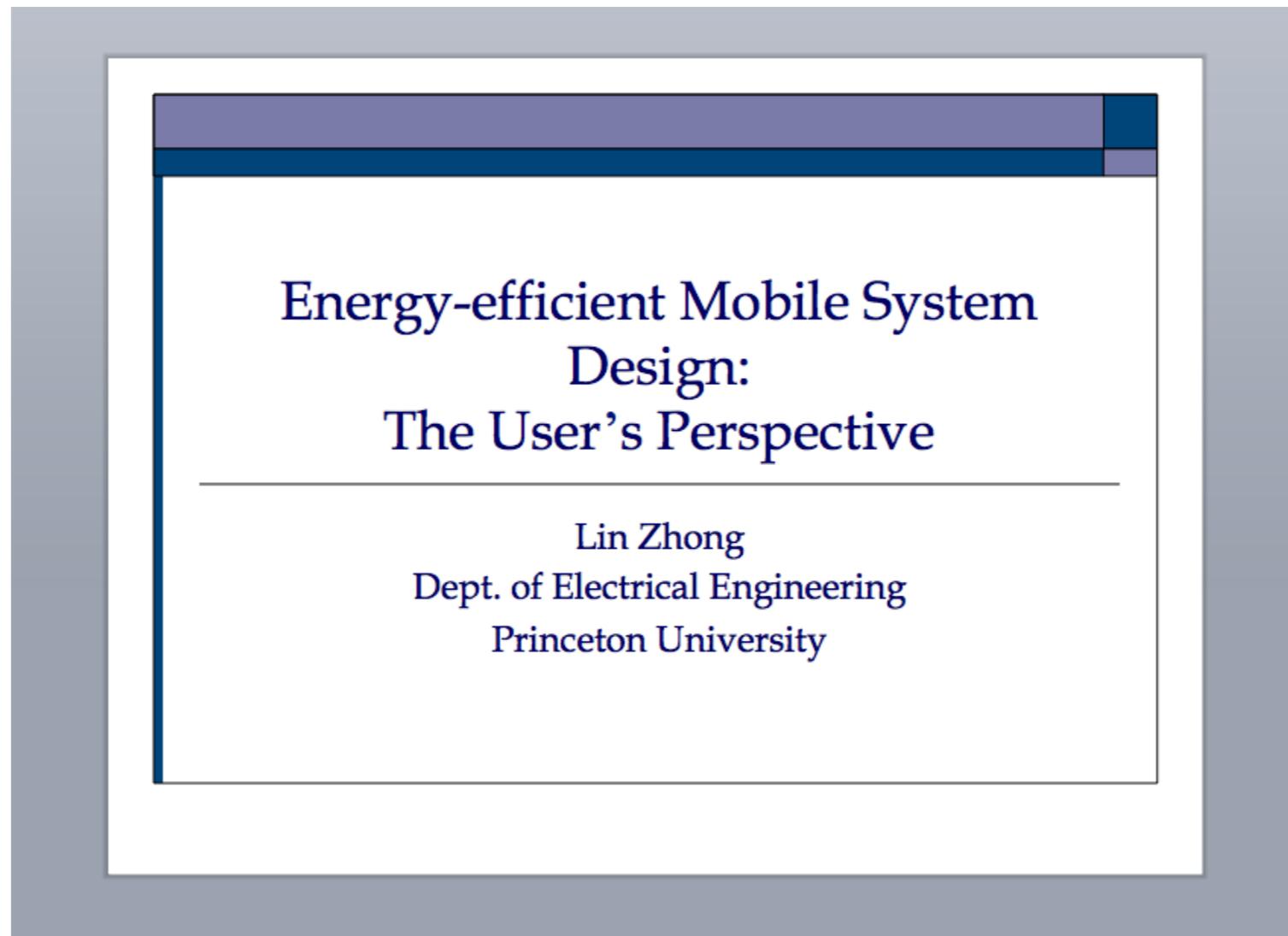
Energy Efficiency of Handheld Computer Interfaces: Limits, Characterization and Practice *

Lin Zhong and Niraj K. Jha
Department of Electrical Engineering
Princeton University
Princeton, NJ 08544
{lzhong, jha}@princeton.edu

$$\text{Energy efficiency} = \frac{\text{User productivity}}{\text{Average power consumption}}$$

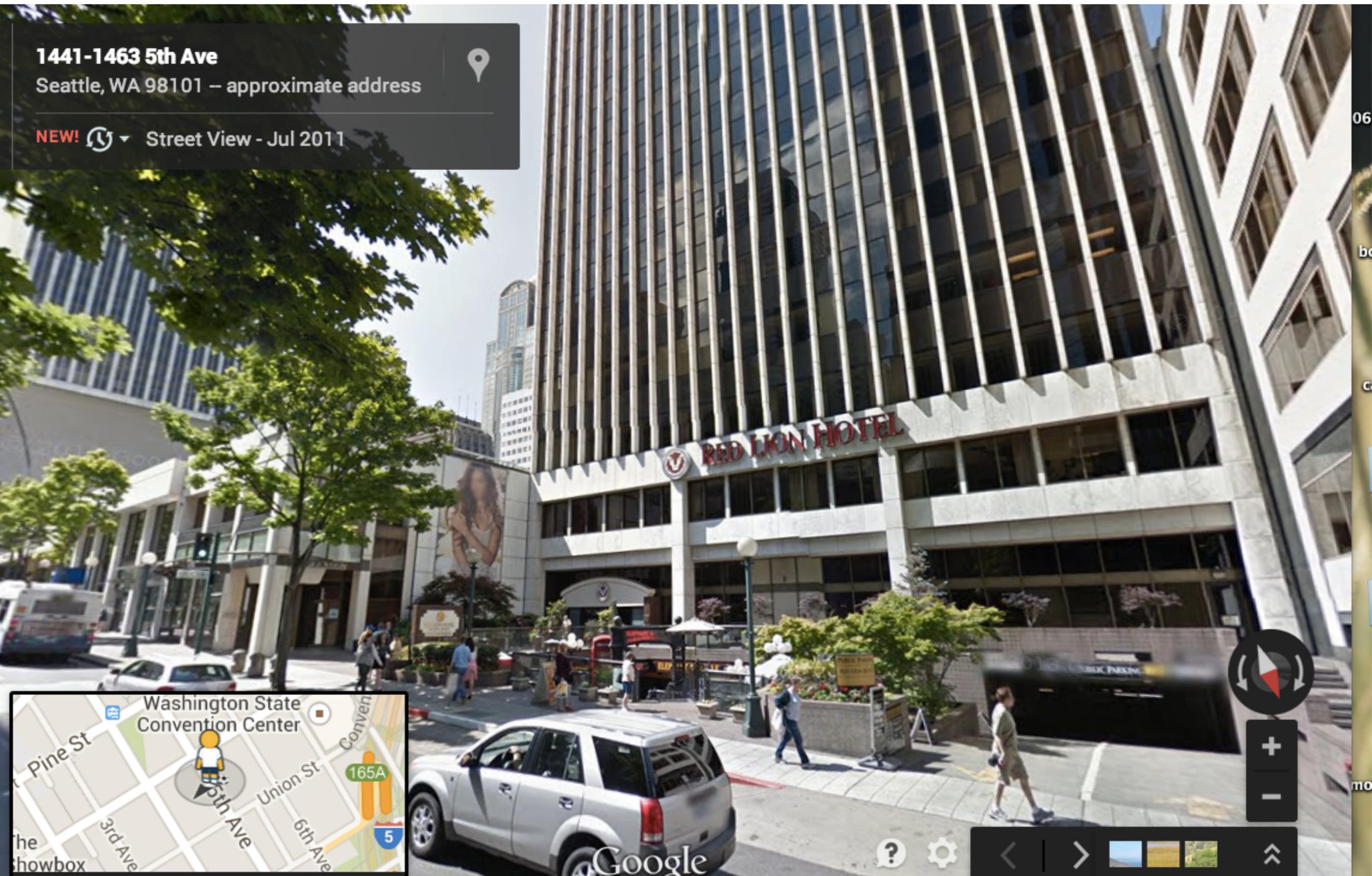


Looking for a job



Interview at Rice on 02/14/2005

MobiSys 2005



MobiSys 2005

WALRUS:

Wireless Acoustic Location with Room-Level Resolution using Ultrasound

Gaetano Borriello^{1,2}, Alan Liu¹, Tony Offer¹, Christopher Palistrant¹, Richard Sharp³

¹*Department of Computer Science & Engineering, University of Washington, Seattle, WA [USA]*

²*Intel Research Seattle, Seattle, WA [USA]*

³*Intel Research Cambridge, Cambridge [UK]*

{gaetano@cs.washington.edu}

Slingshot: Deploying Stateful Services in Wireless Hotspots

Ya-Yunn Su and Jason Flinn

Department of Electrical Engineering and Computer Science

University of Michigan

MobiSys 2005

WALRUS:

Wireless Acoustic Location with Room-Level Resolution using Ultrasound

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Slingshot: Deploying Stateful Services in Wireless Hotspots

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Department of Electrical Engineering and Computer Science

University of Michigan



MobiSys 2005

Reincarnating PCs with Portable SoulPads

Ramón Cáceres Casey Carter Chandra Narayanaswami Mandayam Raghunath

IBM T.J. Watson Research Center

{caceres, chandras, mtr}@us.ibm.com, casey@carter.net

Authors listed in alphabetical order

Best Paper Award

SoulPads led me to research in separating software states from hardware, including Satya's work in Internet suspend & resume and cyber foraging.

Turducken: Hierarchical Power Management for Mobile Devices

Jacob Sorber Nilanjan Banerjee Mark D. Corner Sami Rollins[†]

*Department of Computer Science
University of Massachusetts, Amherst, MA
{sorber, nilanb, mcorner}@cs.umass.edu*

[†]*Department of Computer Science
Mt. Holyoke College, South Hadley, MA
srollins@mtholyoke.edu*

Turducken inspired me about the opportunities from heterogeneous hardware.

Texas, here I come



<http://americancowboy.com/sites/default/files/cowboysunset.jpg>

Edward the network QoS guy



Had started doing wireless work with a serious deployment



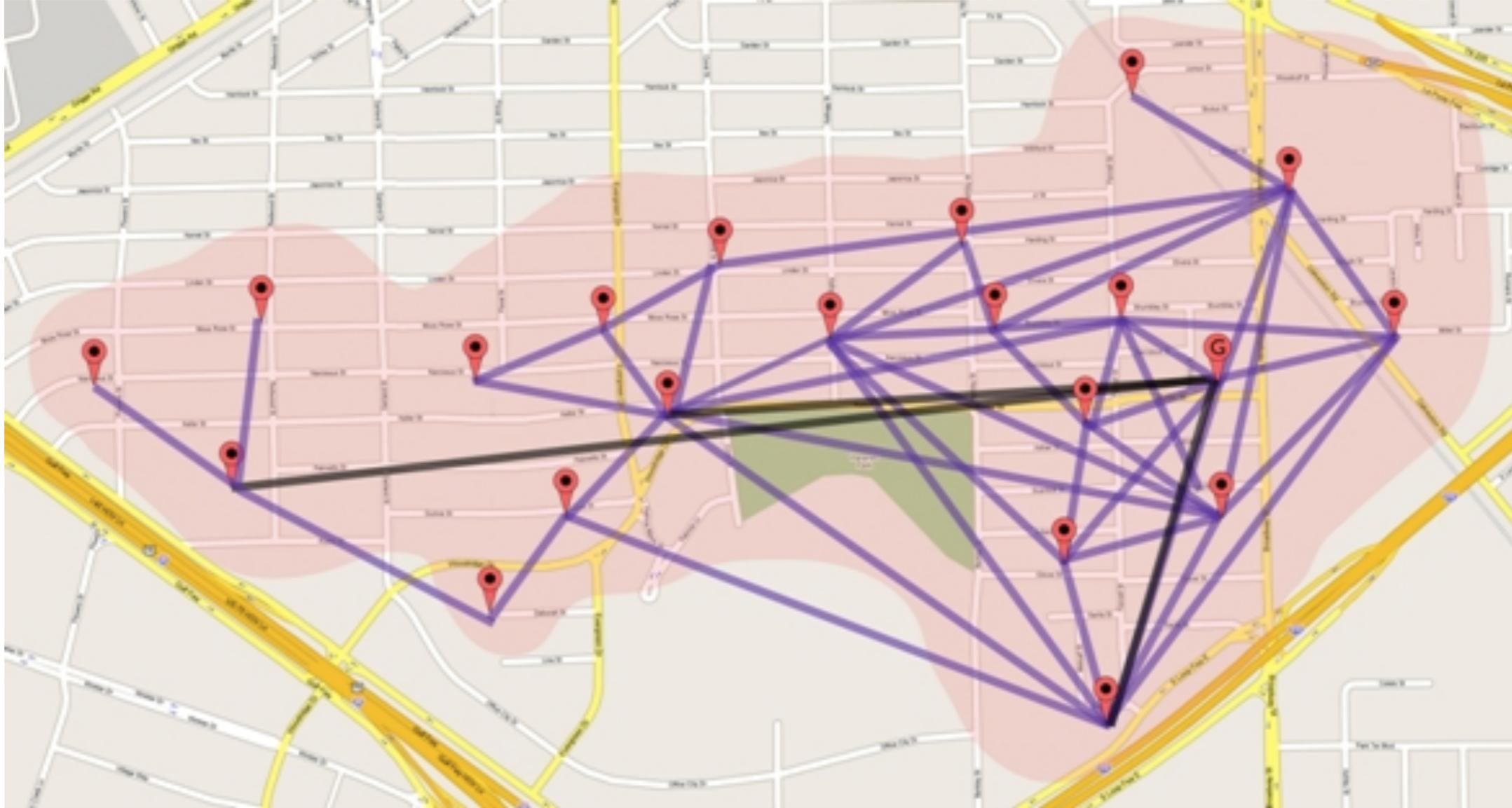
Pecan Park, Houston, TX;
Average household income below US poverty line









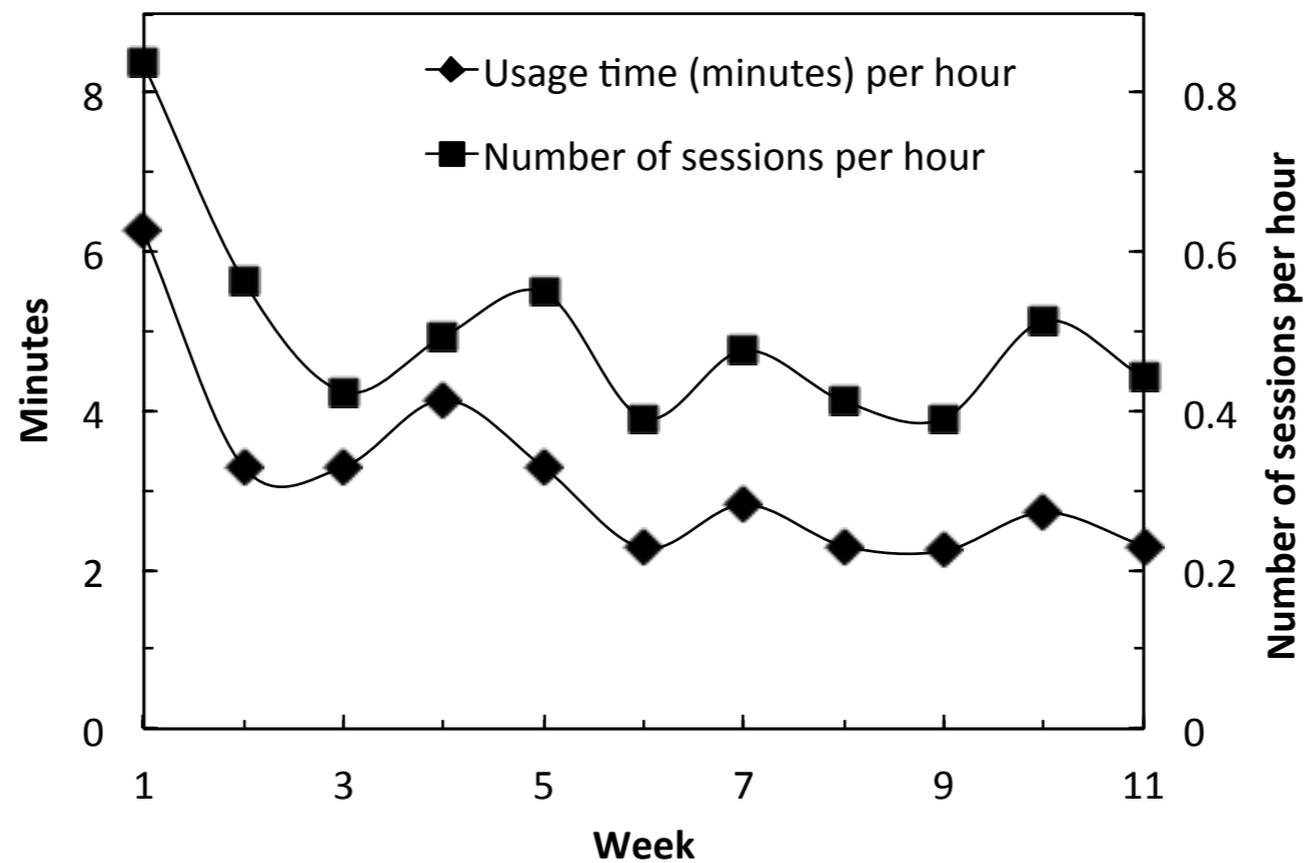


Took a free ride with Edward's connection with Pecan Park



Studying Smartphone Usage: Lessons from a Four-Month Field Study

Ahmad Rahmati, *Member, IEEE*, and Lin Zhong, *Member, IEEE*



Lesson learned: it was too short; there was no control group.

LiveLab: A yearlong field study of 34 iPhone 3GS users

Exploring iPhone Usage: The Influence of Socioeconomic Differences on Smartphone Adoption, Usage and Usability

Ahmad Rahmati¹, Chad Tossell², Clayton Shepard¹, Philip Kortum², and Lin Zhong¹

¹Dept. of Electrical and Computer Engineering, ²Dept. of Psychology, Rice University, Houston, TX
{rahmati, chad.tossell, cws, pkortum, lzhong}@rice.edu



ACM MobileHCI 2012

<http://livelab.recg.rice.edu>



12 months and three control groups

Ashu the information theoretician

of such a system employing a beamformer codebook with N beamforming vectors (corresponding to $\log_2(N)$ bits of feedback per frame) is bounded below as

$$P_{\text{out}}(R, P) \geq 1 - Ne^{-\gamma_0} + e^{-\gamma_1} \sum_{k=0}^{t-1} \left(\frac{N(\gamma_1 - \gamma_0)^k - \gamma_1^k}{k!} \right) \quad (33)$$

where

$$\gamma_0 = \frac{2^R - 1}{P} \quad \text{and} \quad \gamma_1 = \frac{\gamma_0}{\left(1 - \left(\frac{1}{N}\right)^{\left(\frac{1}{t-1}\right)}\right)}. \quad (34)$$

Proof: Let \mathcal{C} be an arbitrary beamformer codebook with N beamforming vectors. Let $P_{\text{out}}^c(R, P)$ be the probability of no-outage when \mathcal{C} is used for beamforming. We have

$$P_{\text{out}}^c(R, P) = \int_{\gamma=0}^{\infty} P_{\text{out}}^c(R, P \mid \|\mathbf{h}\|^2 = \gamma) p_{\gamma}(\gamma) d\gamma.$$

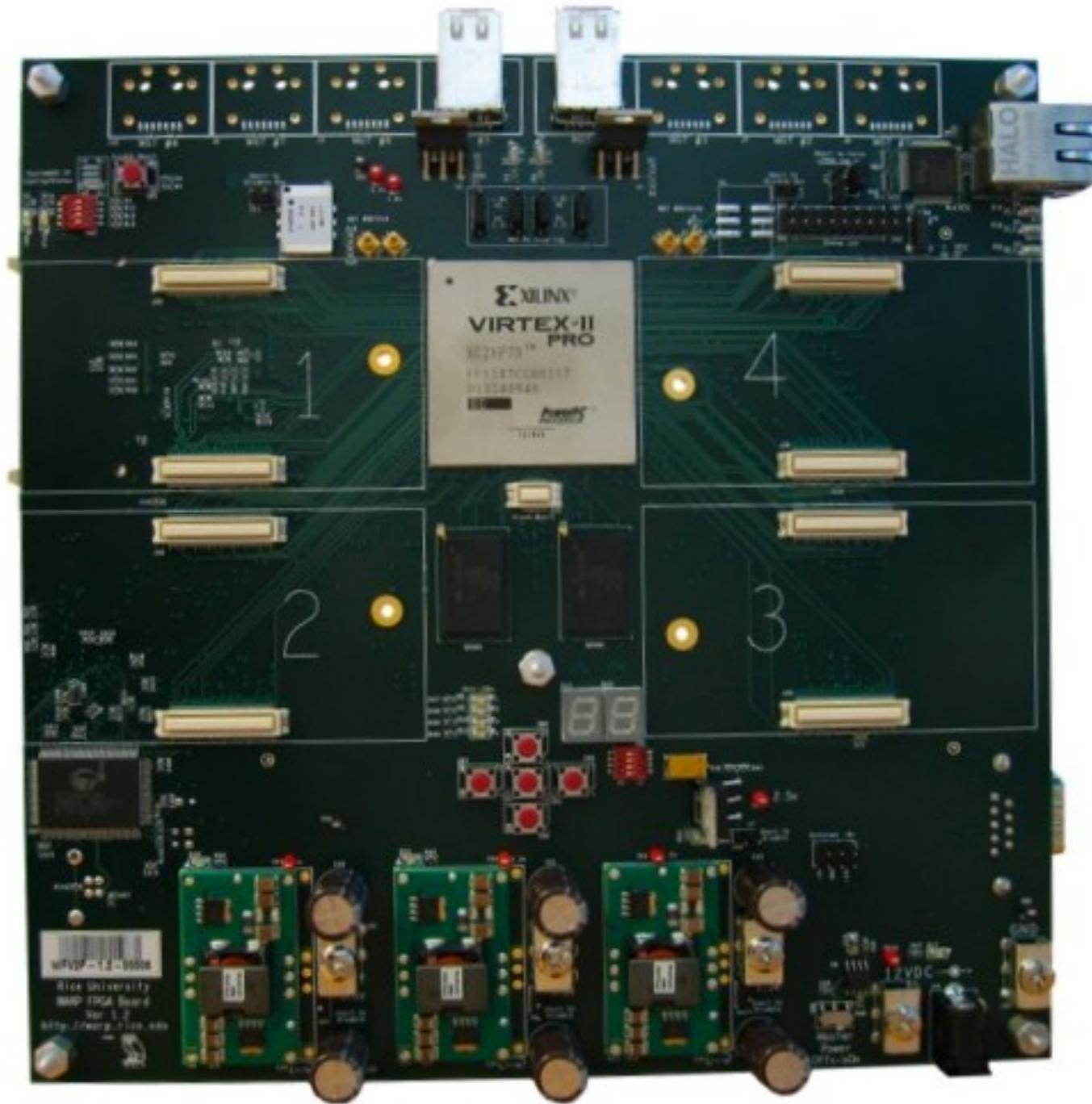
Using the upper bound on $P_{\text{out}}^c(R, P \mid \|\mathbf{h}\|^2 = \gamma)$ from (30) and the distribution of γ in (31), we get

$$P_{\text{out}}^c(R, P) = \int_{\gamma=0}^{\infty} P_{\text{out}}^c(R, P \mid \|\mathbf{h}\|^2 = \gamma) p_{\gamma}(\gamma) d\gamma$$



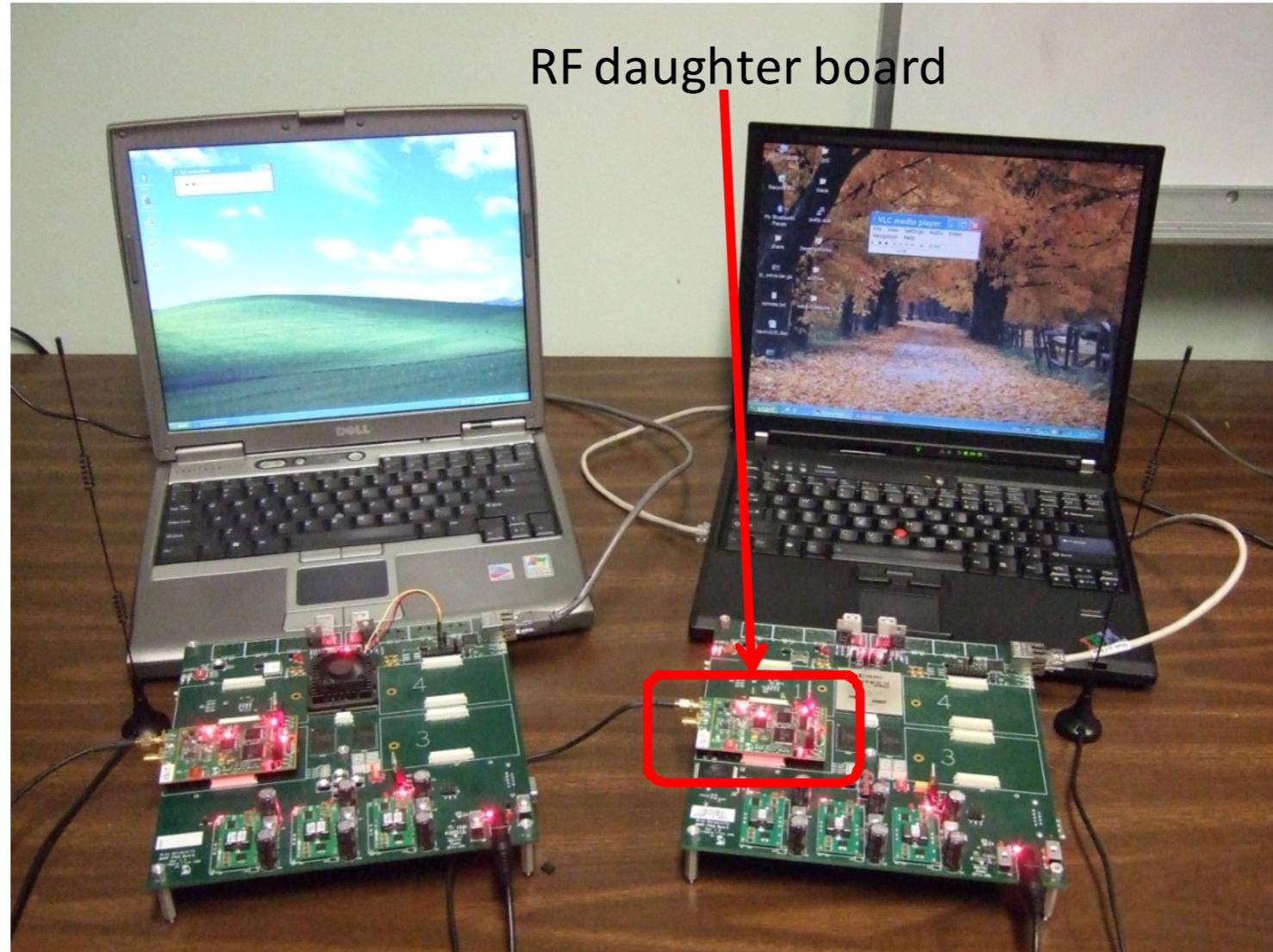
An average Ashu paper would have more than 50 numbered equations and 10 proof.

Ashu the information theoretician



Yet he built this gorgeous 12 layer board with FPGA and multiple antennas called WARP to answer questions from information theory.

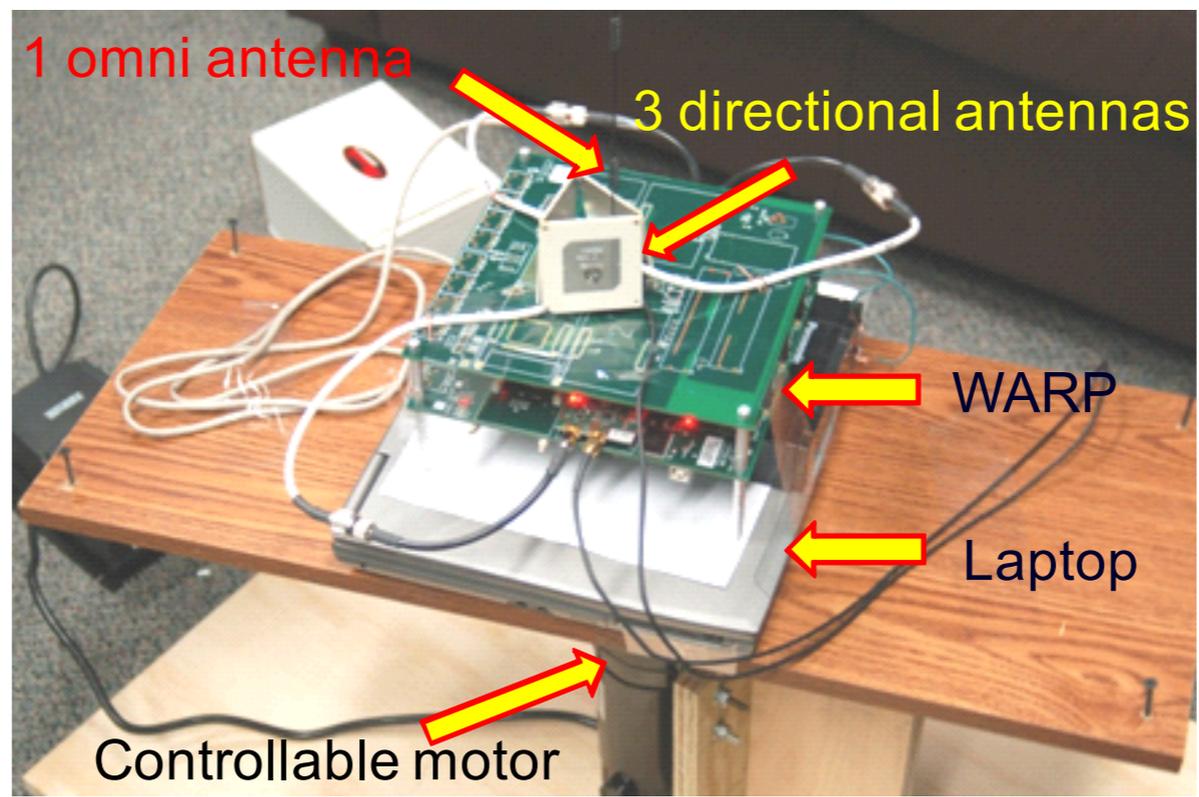
If an information theoretician can build it, I could play with it



WARP Board 1:
Access Point

WARP Board 2:
Wireless interface with μ PM

Micro power management (MobiSys'08)



Directional antennas (MobiCom'10)

Six years after my first MobiSys paper



Chameleon (MobiSys'11 Best Paper Award)

My Rockstar citation



“understanding mobile design tradeoffs,
driven by novel platforms and
large longitudinal studies of mobile users.”



1. Follow the passion

Be true about yourself

High-level synthesis is a great research topic and still a hard problem. Researchers like Jason Cong from UCLA who worked on it about the same time as we did made a huge scholarly & industrial impact. But it didn't click with me.

2. Do it better each time



It is fine to start low



Aim high

It takes time. It took me five year to have my first MobiSys paper; another six year to have my first MobiSys Best Paper Award.

2.a Get out of the comfort zone



Be true about the research problem

Don't change the problem so that you can solve it
Reinvent yourself to solve the problem

2.b Have role models

Not to copy their research but to analyze their approaches



I was lucky to discover Jason early on



<http://static.guim.co.uk/sys-images/Guardian/Pix/pictures/2014/2/14/1392396056634/Mount-Everest-rises-8848m-011.jpg>

Your role models do it better each time too:
Jason has won five Best Paper awards since MobiSys'04:
3 SOSP/OSDI, 1 ASPLOS and 1 FAST

My Rock Band

Students (by seniority)



Collaborators (by alphabet)



1. Follow the passion
2. Do it better each time