Microsoft Research

Green IT

A Software Perspective

Victor Bahl

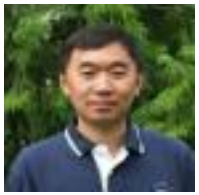
SIGCOMM Green Workshop, August 30, 2010

Acknowledgments & Credit


Agarwal


Chandra


Goraczko


Liu


Kansal


Nath


Padhye

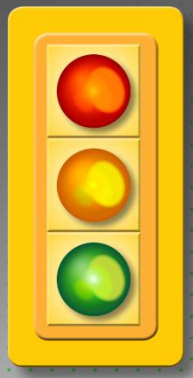

Reich


Zhao

Environmental Sustainability

REDUCING
energy demands

MANAGING
energy and environmental footprint



RETHINKING
business practices

…while improving the bottom line

Home & Office Computing

Battery Powered Computers

Lenovo X61 laptop

Power: 0.74W (sleep) to **16W** (active)

"Wall Powered" Computers

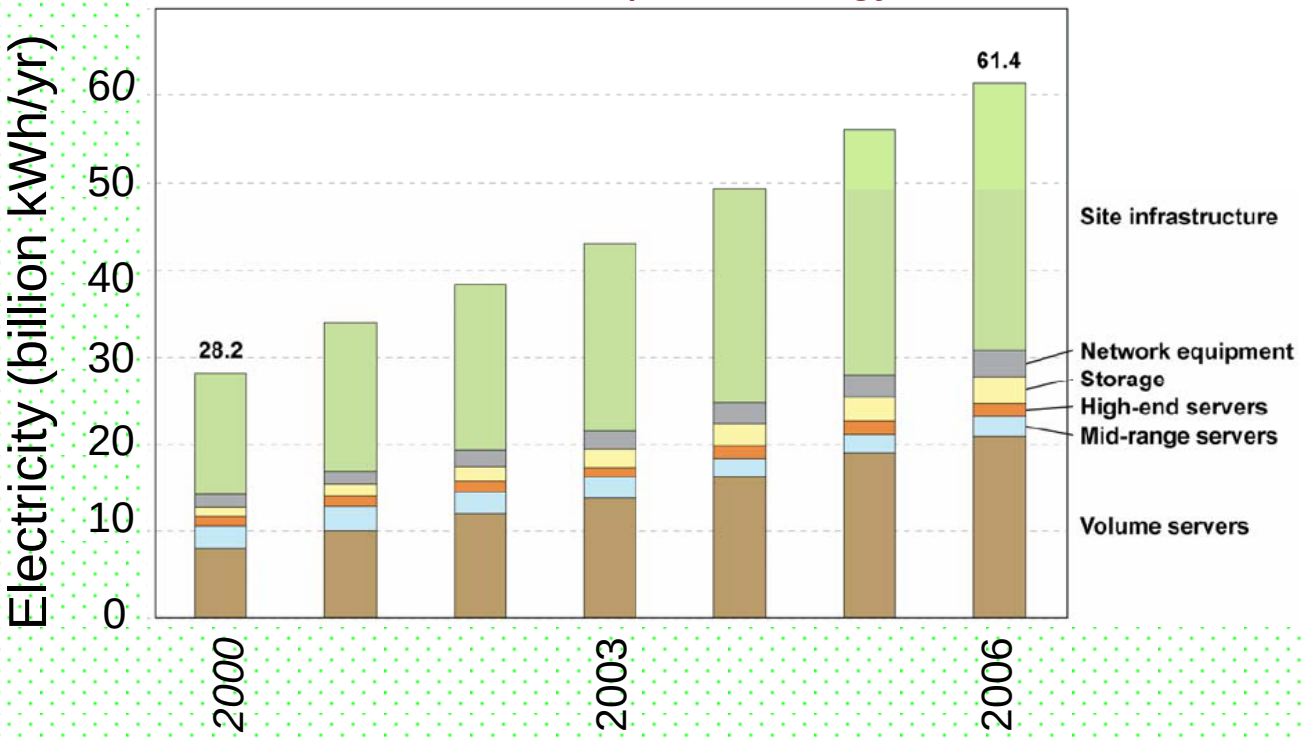
Dell Optiplex 745 desktop

Power: 1.2W (sleep) to **>140W** (active)

- **67%** of office PCs are left on after work hours
  - Robertson et. al.: *After-hour power status of office equipment and energy usage of plug-load devices*. LBNL report #53729
- Home PCs are left on for **34%** of the time
  - **50%** of the time they are not being used
- 600+ desktops always left on (total=700+)
  - Agarwal et. al: *Sombiloqui, Augmenting network Interfaces to reduce PC energy* (NSDI 2009)
- Almost all desktop machines in MSR are left on after work hours

Enterprise & Datacenter Computing

Source: US Dept. of Energy



Est. Cost: $4.5B

Energy usage growing at 14% yearly

Datacenter energy (excluding small DC's, office IT equip.) equals electricity used by the entire U.S transportation manufacturing industry (manufacture of automobiles, aircraft, trucks, and ships)

Long Term Energy Forecasts

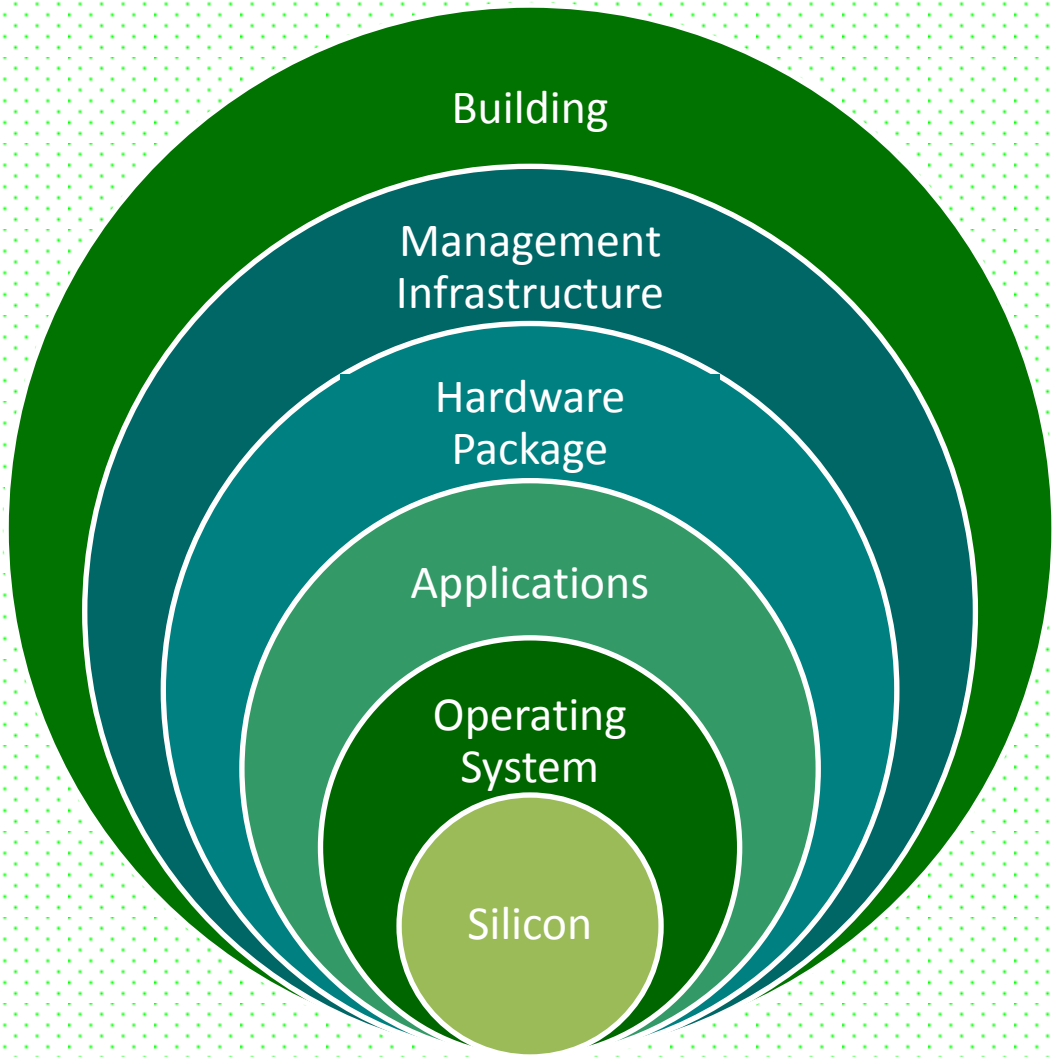
- EPA estimated, in 2006 datacenters in the US used 61 billion KWH or 1.5% of the energy used in the country
- EPA's Prediction: By 2011, datacenters in the US would use up to 100 billion KWH with a total cost of $7.4 billion and an estimated emissions impact of 59 million metric tons of CO2
- By 2030 214 GigaWatts of *new* generation capacity are expected to be needed
- The electric utility industry will need to make a total infrastructure investment of $1.5 - 2.0 Trillion

Energy efficiency/demand response programs by electric utilities could reduce the need for new generation capacity significantly; ***dropping the forecast by 38 percent***

Source: Energy Information Administration, EPRI

Opportunities to Reduce Power

A Holistic View



Improve Data Center PUE
Increase Facility Utilization

Increase Server Utilization
Centralized Power Management

Rightsizing & Subsystem Balancing
Power Supply Efficiency
Remove Unnecessary Components

Energy Efficient & Aware Applications

Platform Power Management
Energy Source Aware

Variable-power components
Lower-power components

PUE: Power Usage Effectiveness (ratio of total power over IT power)

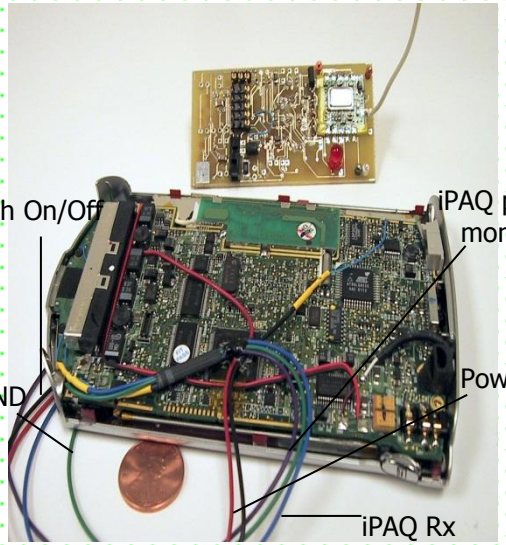
In the beginning….

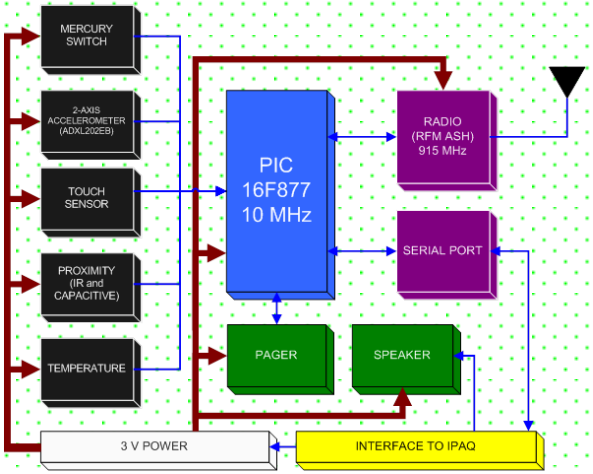
SmartPhone Energy Management

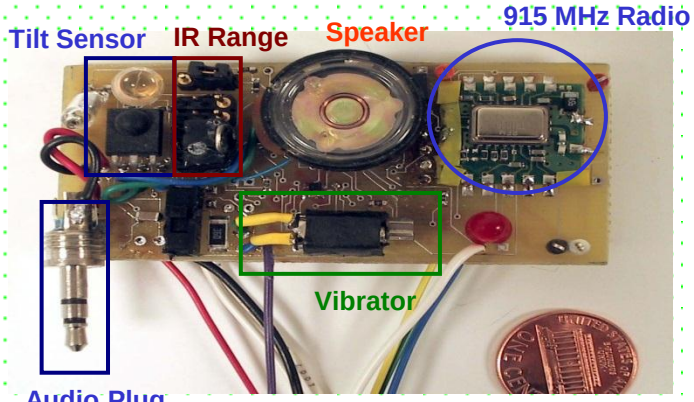
….was all about sleeping

Wake on Wireless (2001-02)

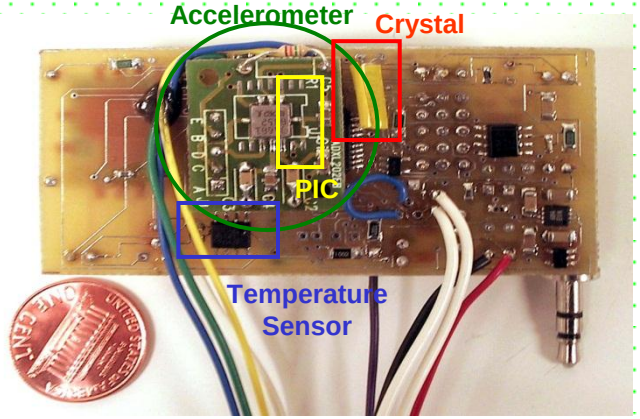
LPR to a Trigger Wakeups







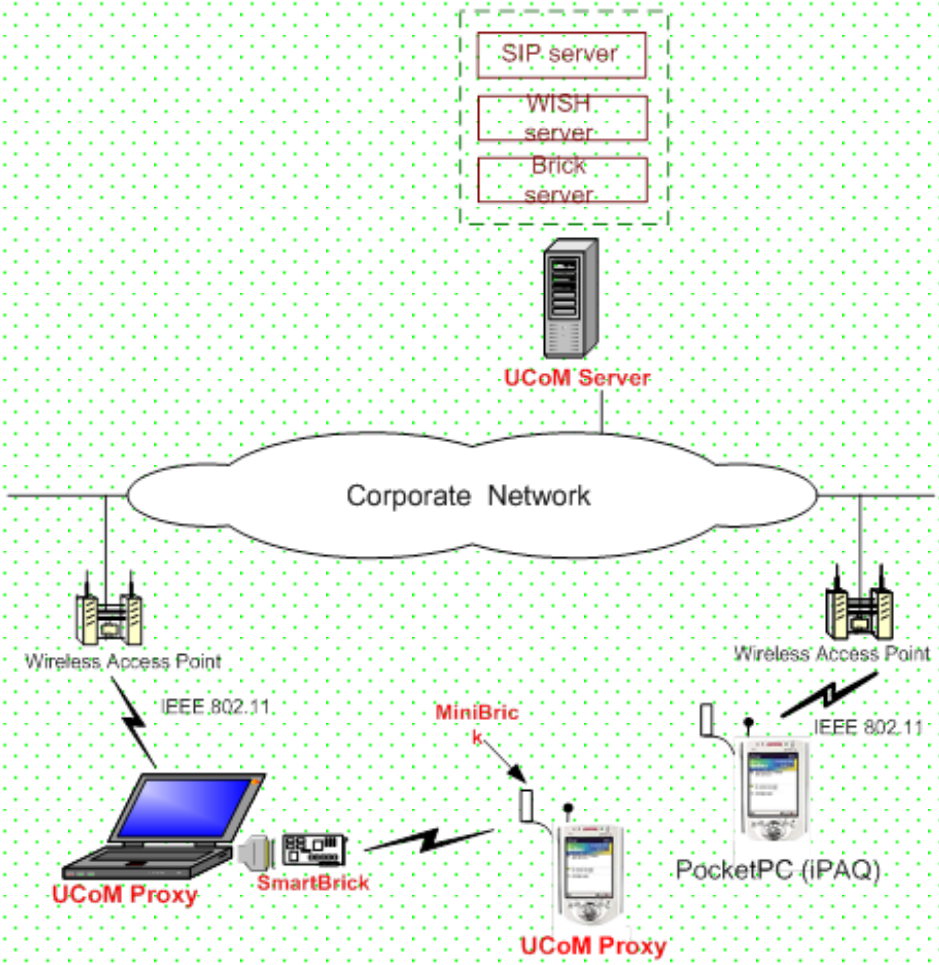
Front View



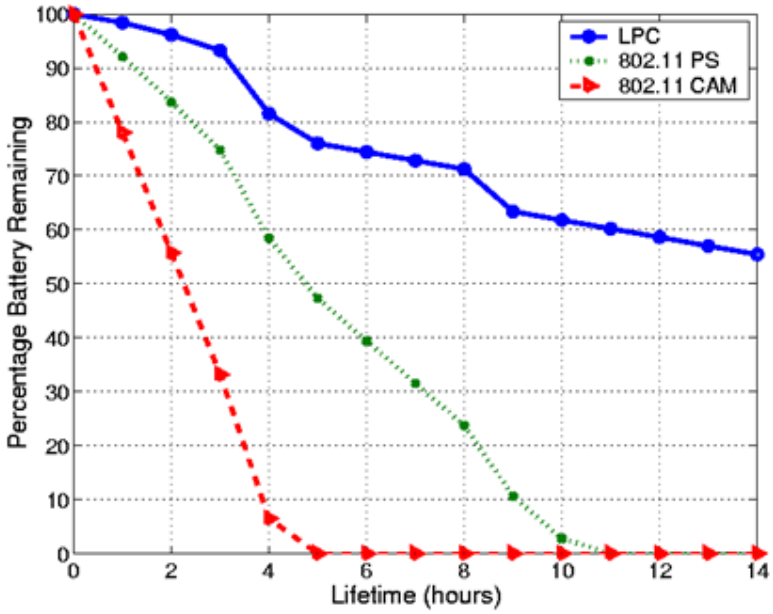
Back View

Wake on Wireless with Low Power Radio

Energy Saving



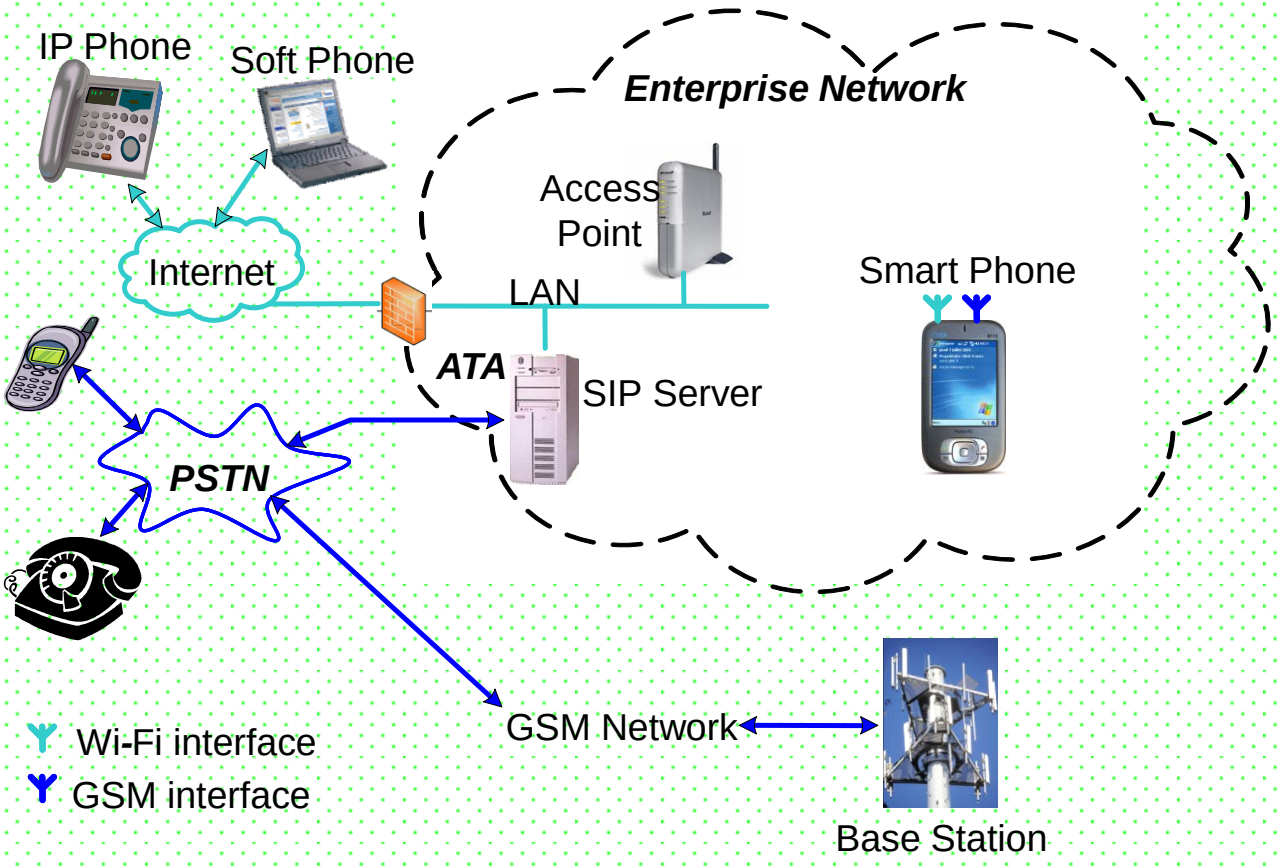
2001-02



Wake on Wireless (2005-07)

Cell Network as a Trigger Mechanism

- Turn off Wi-Fi interface if Smartphone not in VoIP call
- Notify incoming call using “ring” on GSM interface
  - Turn on Wi-Fi interface and complete call over Wi-Fi
- Turn off Wi-Fi interface on call completion

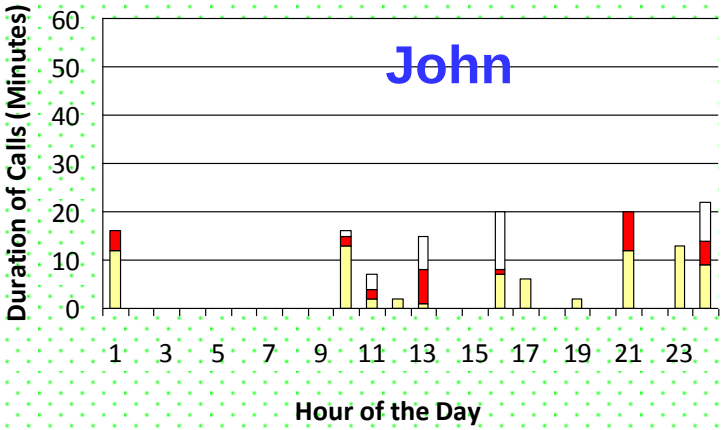


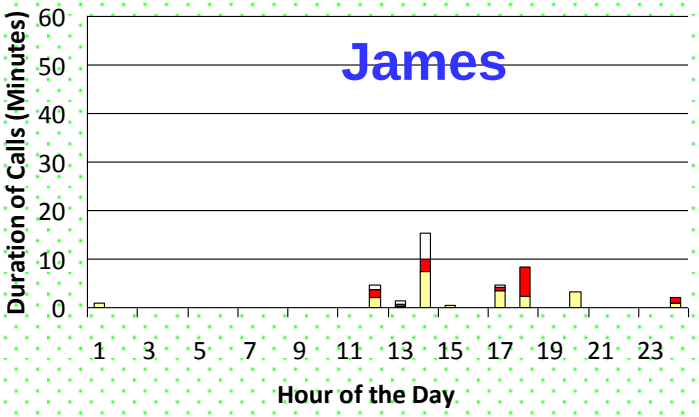
Security: SIP Server uses different caller ID every time

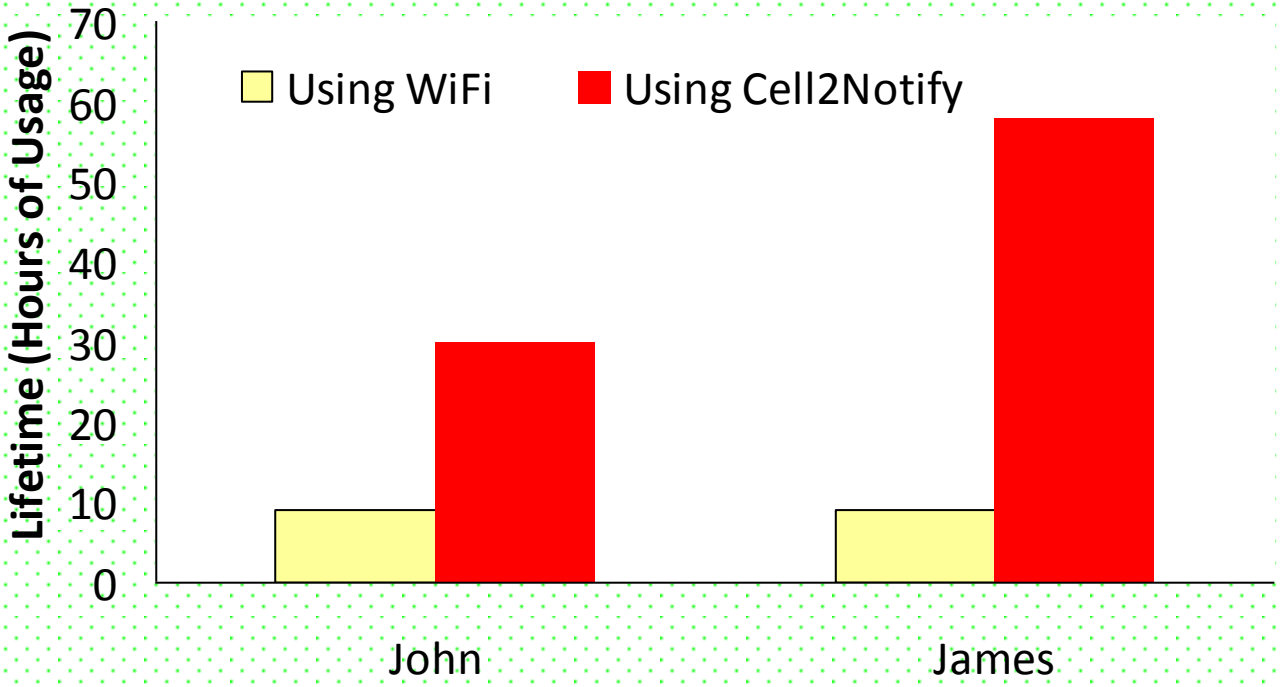
Wake on Wireless with Cell2Notify

MobiSys 2007

Energy Savings







… then we extended sleeping to home & enterprise

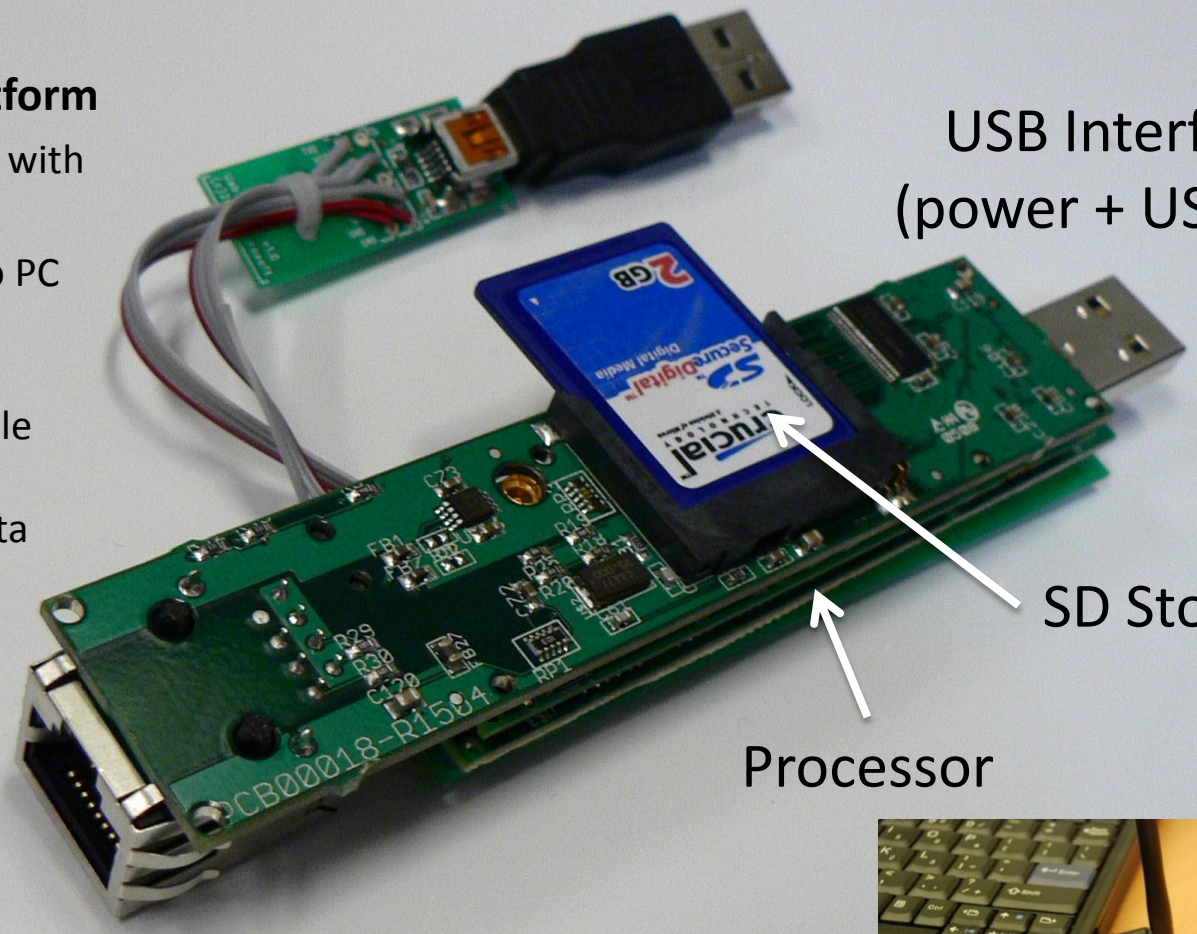
Home & Enterprise Energy Management

- WaMu, Dell and GE save of millions of dollars per year w./ propriety solutions (Citation: Dog Washburn: *How much money are your idle PC wasting (Forrester, December 2008)*
- UCSD CS department estimates it can cut 25% of total energy bill (Agarwal et. al: *Somniloqui, Augmenting network Interfaces to reduce PC energy usage (NSDI 2008)*

Somniloquy

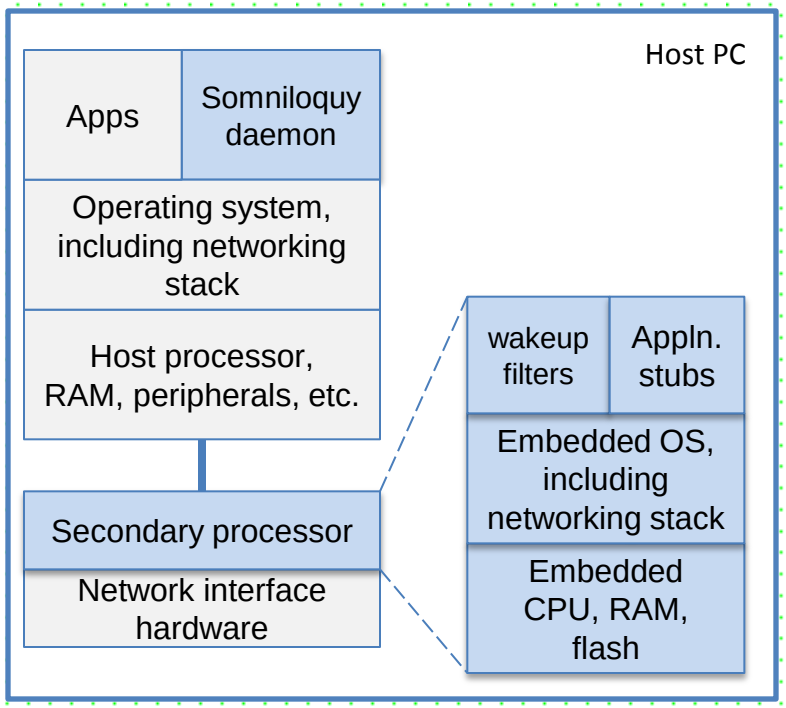
Uses "gumstix" platform

- PXA270 processor with full TCP/IP stack
- USB connection to PC for sleep detection/wakeup trigger, power while asleep, and IP networking for data



Somniloquy: PCs that Talk in their Sleep

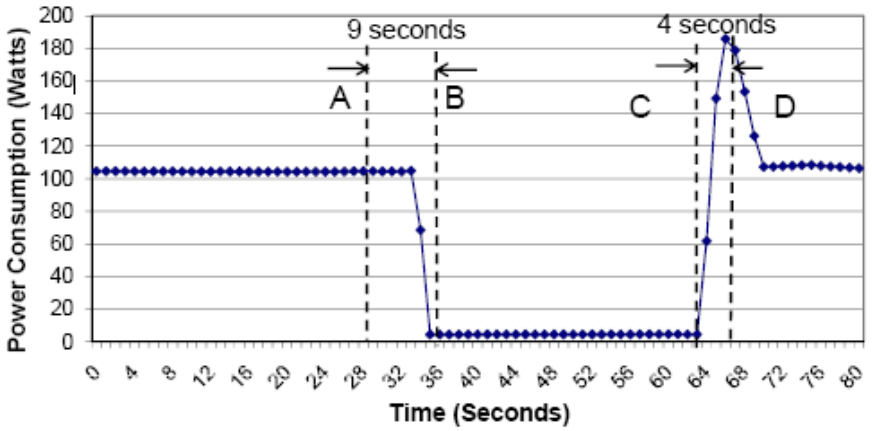
- Augment network interfaces:
  - Add a separate power domain
    - Powered on when host is asleep
    - Processor + Memory + Flash Storage + Network stack
  - Same MAC/IP Address
- Wake up Host when needed
  - E.g. incoming connection
- Handle some applications while PC remains asleep
  - Using “application stubs”



Somniloquy

Power Savings

State	Power
Normal Idle State	102.1W
Lowest CPU frequency	97.4W
Disable Multiple cores	93.1W
"Base Power"	93.1W
Suspend state (S3)	**1.2W**



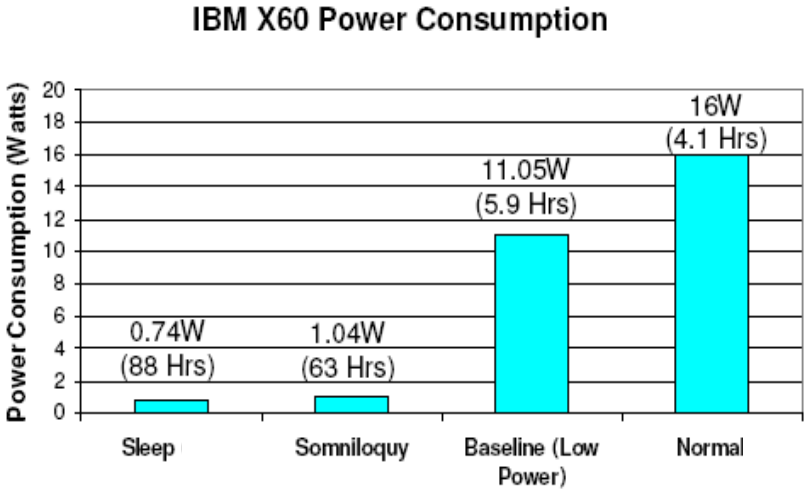
Dell Optiplex 745 Power Consumption and transitions between states

For Desktops

- Power drops from >100W to <5W
- Assuming a 45 hour work week
  - **620kWh saved per year**
  - **US $56 savings, 378 kg CO_2**

For Laptops

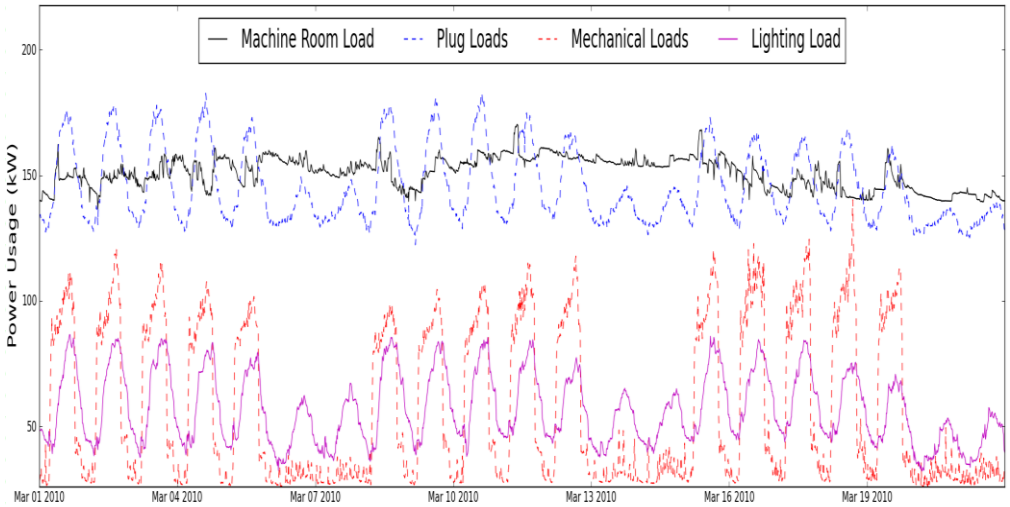
- Power drops from >11W to 1W,
  - **Battery life increases from <6 hours to >60 hours**
- Provides functionality of the "Baseline" state
  - Power consumption similar to "Sleep" state



Enterprise

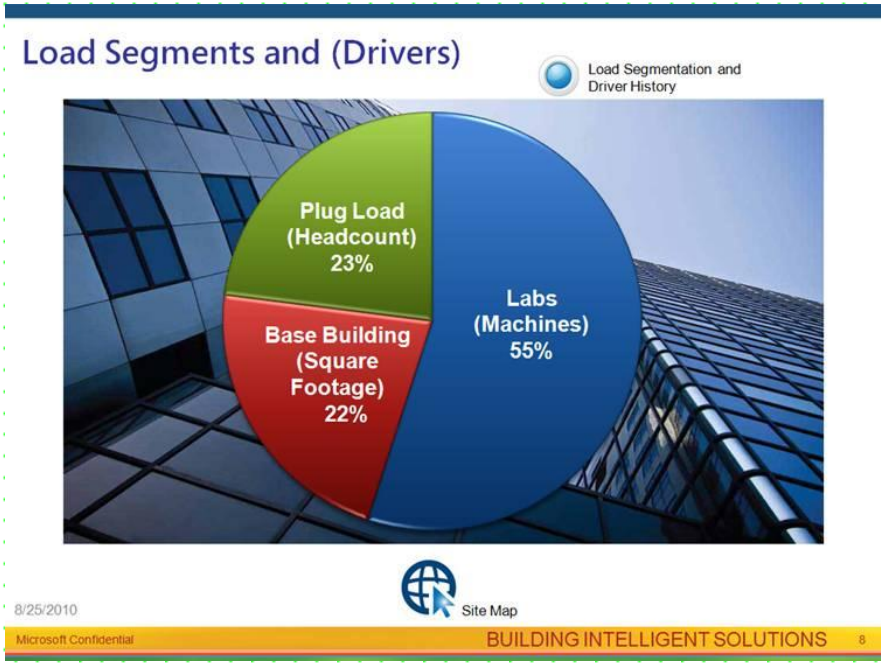
IT Dominates Energy Usage

UCSD CSE Building



Courtesy: Yuvraj Agarwal (UCSD)

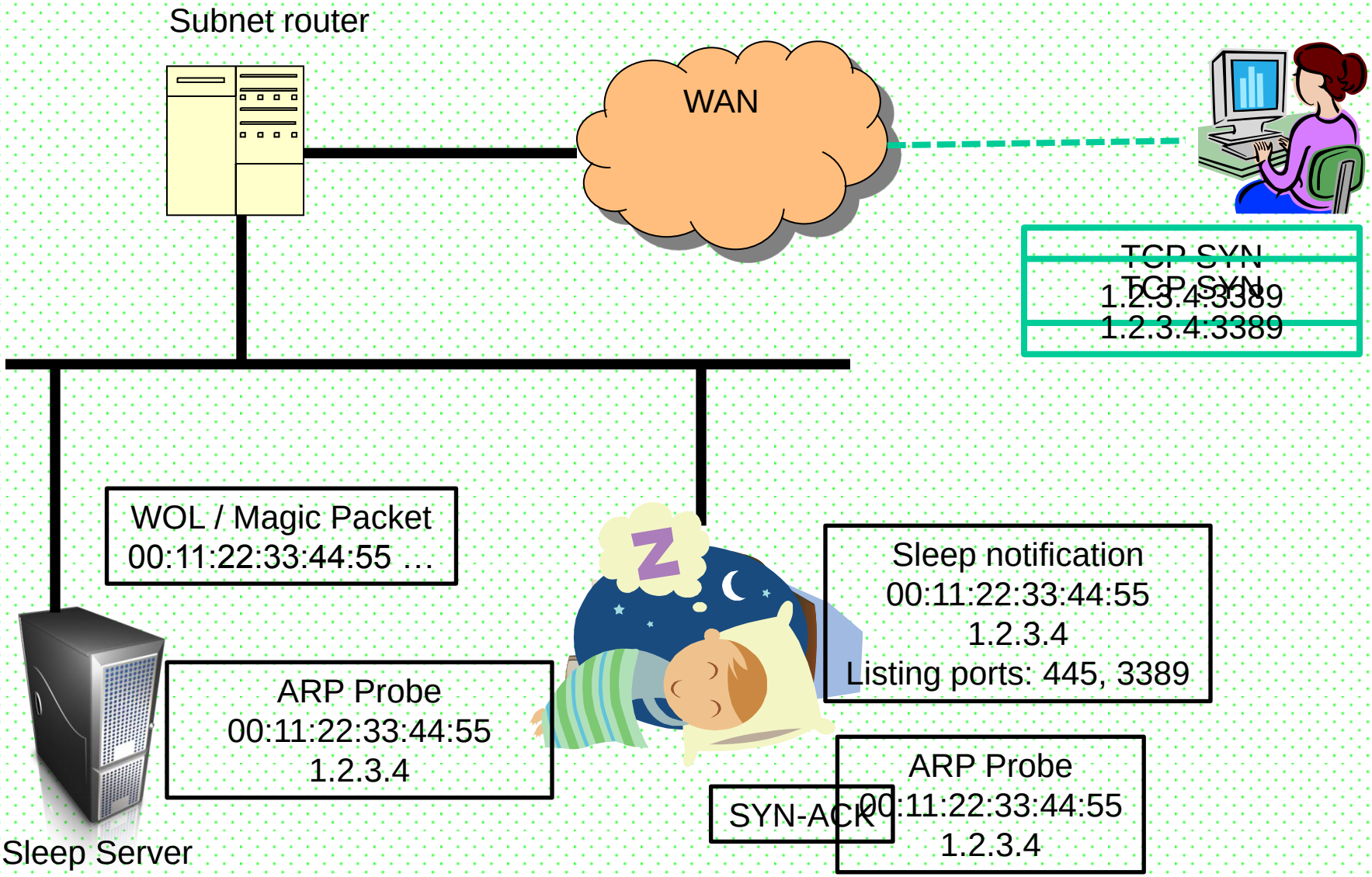
Microsoft Research, Bldg. 99



- IT loads account for 50% (peak) - 80% (off-peak) loads!
  - Includes Plug-Loads (PCs) + Machine Room (Servers)
- Most IT equipment not powered off or `Sleeping'

SleepProxy

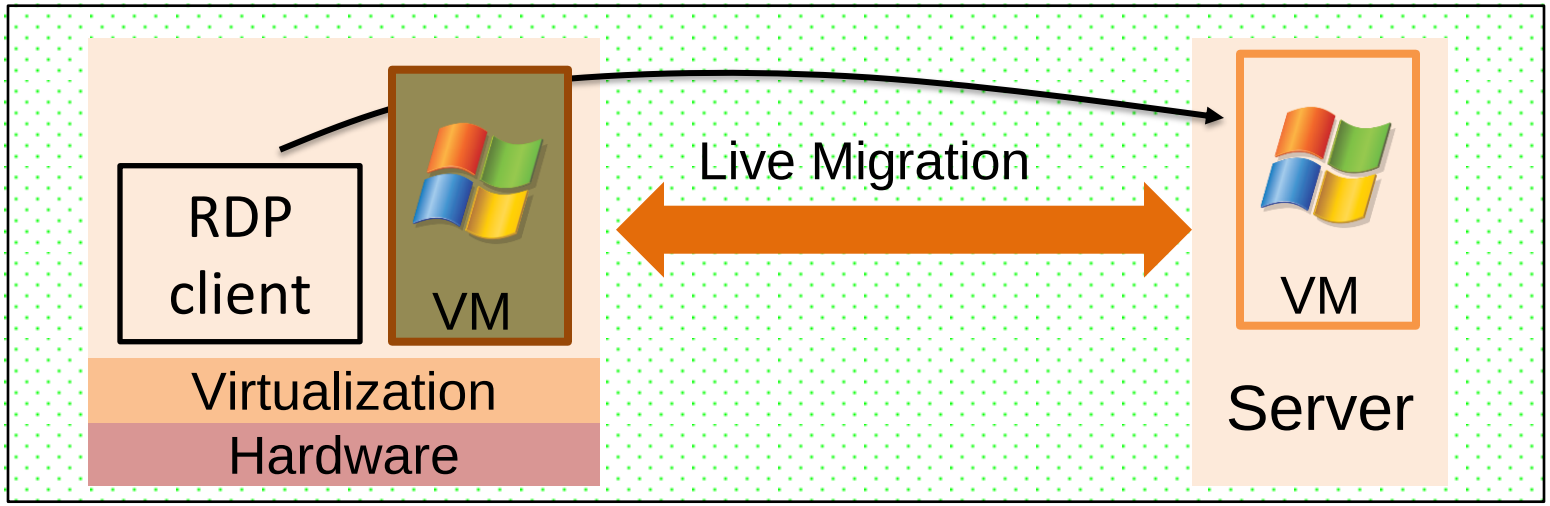
A Software-only Enterprise Solution



Typical machine sleeps > 40% of the time

LiteGreen

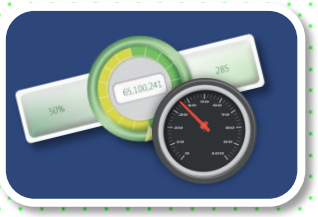
A VM Based Solution



- Prevalence of short idle periods
- Virtualization + Migration to save energy during short and long idle periods while avoiding user disruption
- LiteGreen can help save 60-72% of desktop energy

You Can't Manage what you don't Measure

Turning our attention to transparency & possibly changing behavior….

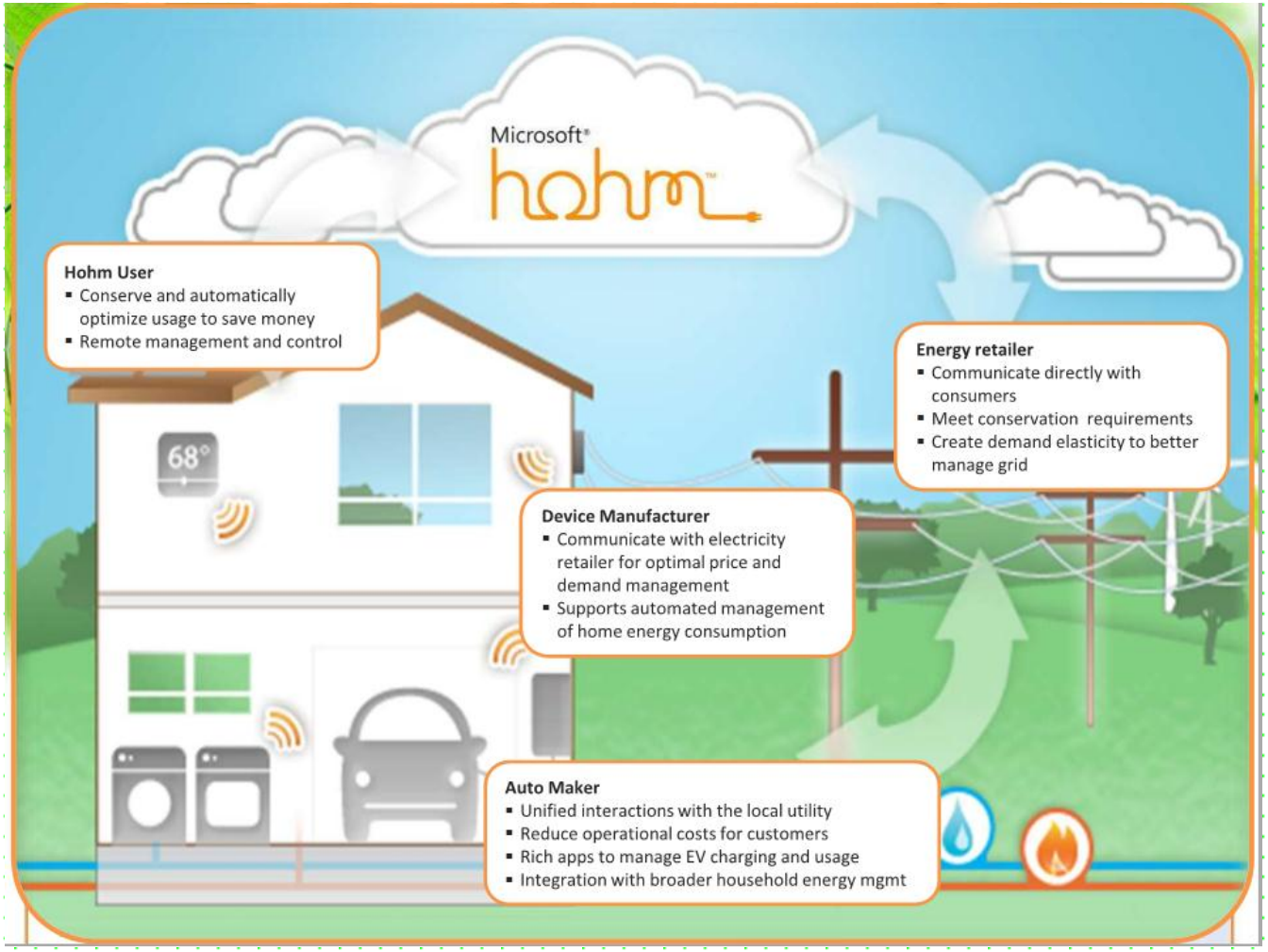


Dashboards and scorecards

- **Streamline data collection for key environmental performance indicators:**
  - ☑ **Direct energy consumption**
  - ☑ **Indirect energy consumption**
  - ☑ **Greenhouse gas emissions from the total energy consumption**
  - ☑ **Greenhouse gas emissions from standard business practices**
- **Analyze status of environmental sustainability initiatives**
- **Share performance broadly across the organization**

Microsoft Hohm

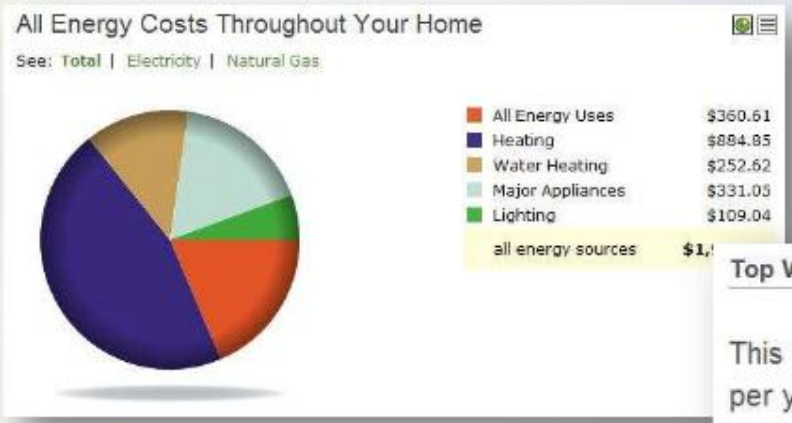
Gartner Inc. *survey: 80% of consumers (in US & U.K) would like to participate in some energy program if it were offered by providers (Nay 2009)*



Victor Bahl, SIGCOMM Green Networking Workshop 2010

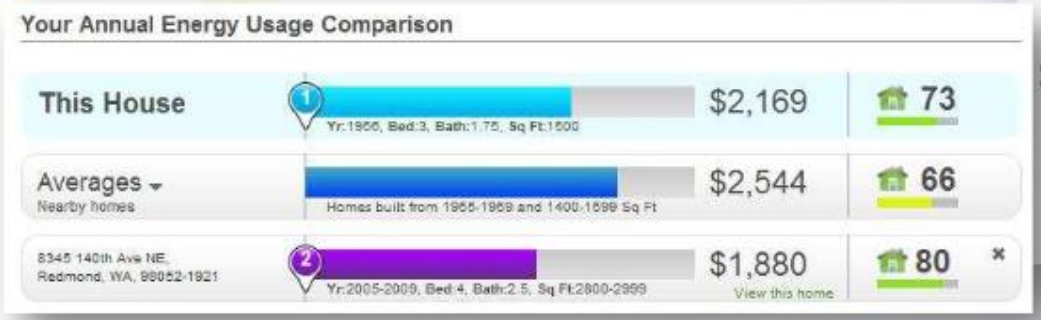
Helping consumers save today

+ Energy usage breakdown to better understand where energy is being consumed



+ Personalized list of improvement recommendations with estimated savings and referrals to local vendors

+ Comparison with others in area to determine relative usage



Annual Energy Breakdown

Energy usage and costs breakdown is determined by many aspects of your home including construction, heating, cooling, lighting, appliance characteristics, and the weather in your area to predict how much energy your home uses. This energy usage estimate is used, along with the rates charged by your energy provider or averages from your area to produce an estimate of your energy usage.

You can learn more by viewing our frequently asked questions.

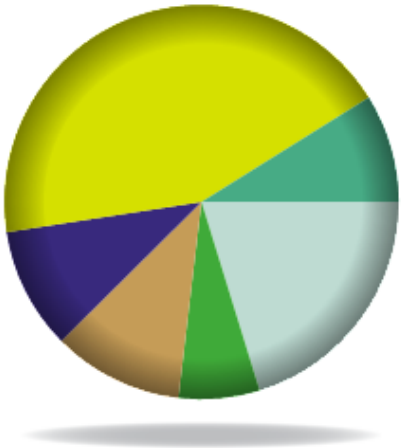
All Energy Uses	$3,917.08
Heating	$1,705.91
Cooling	$391.17
Water Heating	$348.22
Major Appliances	$792.74
Other Appliances	$419.12
Lighting	$259.92

edit home profile

update provider info

All Energy Cost Throughout Your Home

See: **Total** | Electricity | Natural Gas



Major Appliances	$792.74
Lighting	$259.92
Other Appliances	$419.12
Cooling	$391.17
Heating	$1,705.91
Water Heating	$348.22
all energy sources	**$3,917.08**

Overall Carbon Equivalent
24,631.32 lbs. CO_2

Biggest Use
Fuel used to generate heat
$1,635.40

Top Ways to Save

When replacing your central air conditioner, choose a high-efficiency model with a SEER equal to 16
Cost savings up to $184 per year.

Increase attic floor insulation to R-60
Cost savings up to $7 per year

Energy Report

The following energy report has been created for your home based on the information provided in your home profile. It includes a list of recommendations, available energy usage information and an estimated breakdown of where you spend your energy dollars every year.

Your Hohm Energy Report

Print Energy Report

Home Profile: 64% complete
Energy Data: Electricity - Manual, Gas - Manual
Report Generated On: September 16, 2009
Address: 98052

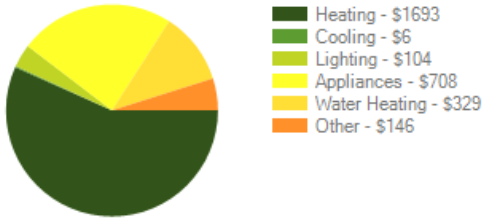
Summary of Potential Savings

Thank you for using our beta service. You can use the following energy report to guide you in your home energy upgrades and repairs. You may want to consult a professional before implementing some of the recommendations. As with any recommendations product, Hohm will improve as more people use our beta.

Your average annual energy costs are **$2,986**. This includes your electricity and gas consumption, but may not include auxiliary energy usage such as propane tanks and generators.

Energy Cost Breakdown and Usage

Your Estimated Energy Costs



Annual Electricity Usage

Average cost per kWh
$0.111

Home Profile

64% complete
Update home profile

Energy Usage

Electricity: Manual
Update/view your usage

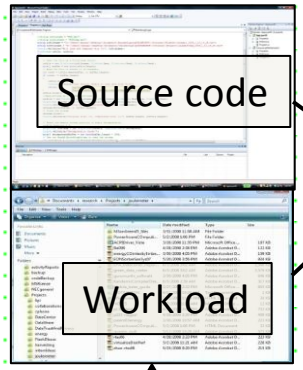
Gas: Manual
Update/view your usage

Energy Report & Recommendations

Available

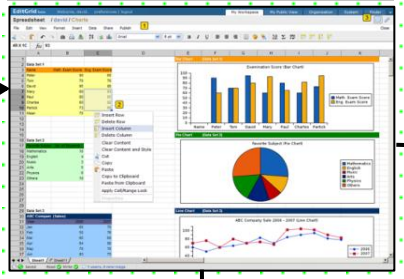
Fine Grained Visibility

Measure application energy usage in depth



JouleMeter

Detailed Energy Profile



Run-time control
(Eg. Reduce QoS)

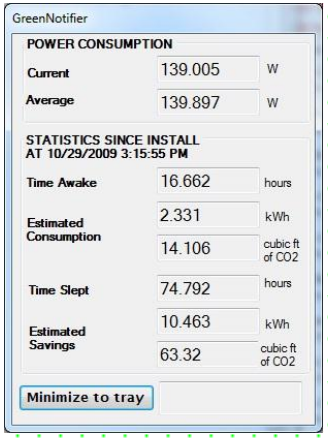
Auto-optimize
(Eg. Compiler warning: Change line 136 in Prog.c to save …)

Designer Insights
(Eg. Network is holding up CPU in method X …)

Optimizations

GreenClient: Provides energy usage stats to user

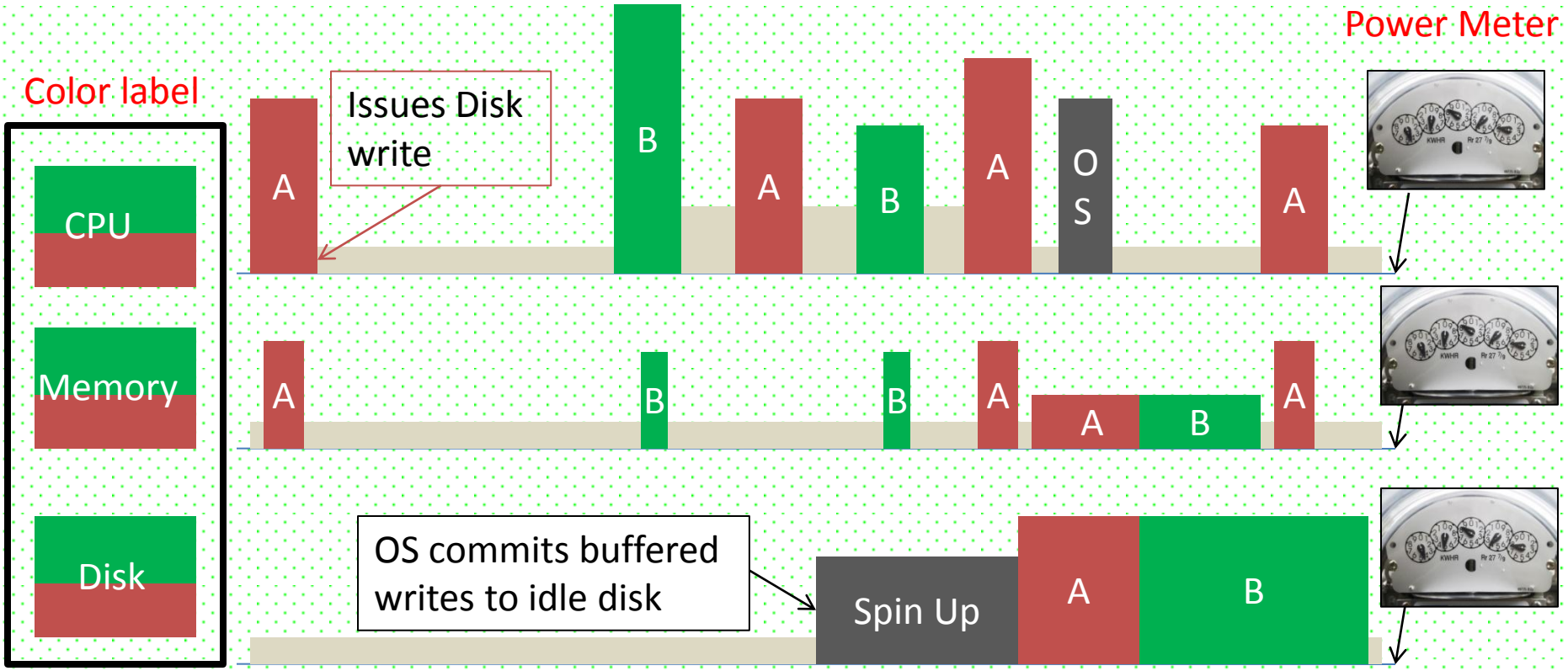
- Current power draw
- Historical savings



Courtesy: Aman Kansal

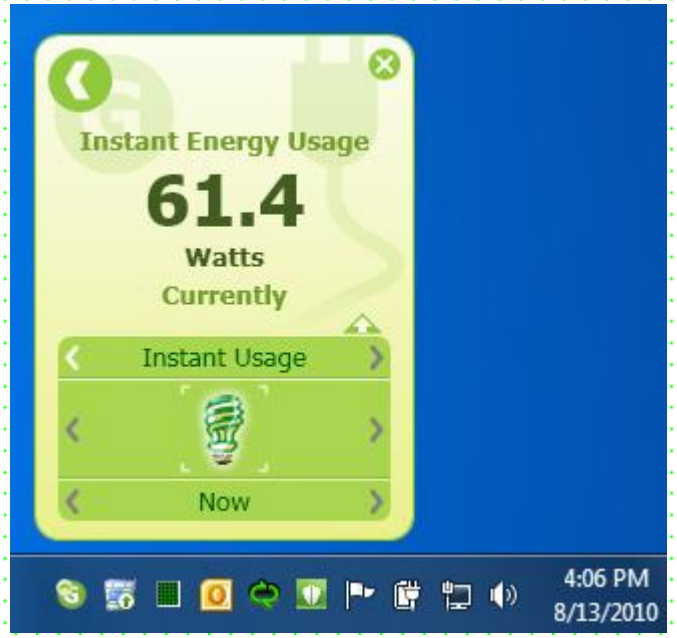
Providing Transparency with Joulemeter

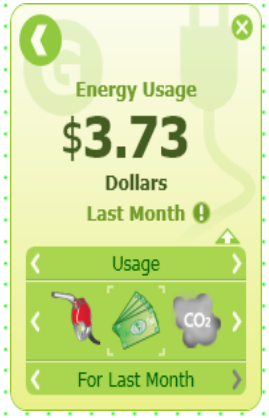
Application Energy Measurement Using Performance Events

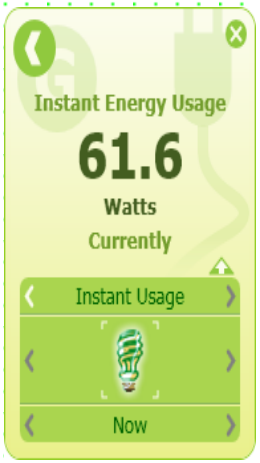


- Energy(App A) = Σ (red rectangles)
  - Other components: Network, GPU, … (Not in current version)

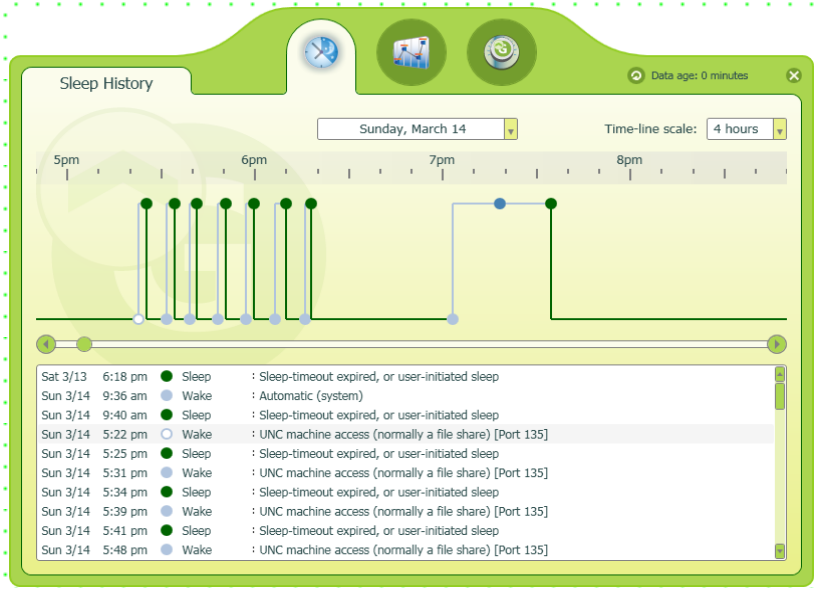
GreenUP: JouleMeter + SleepServer



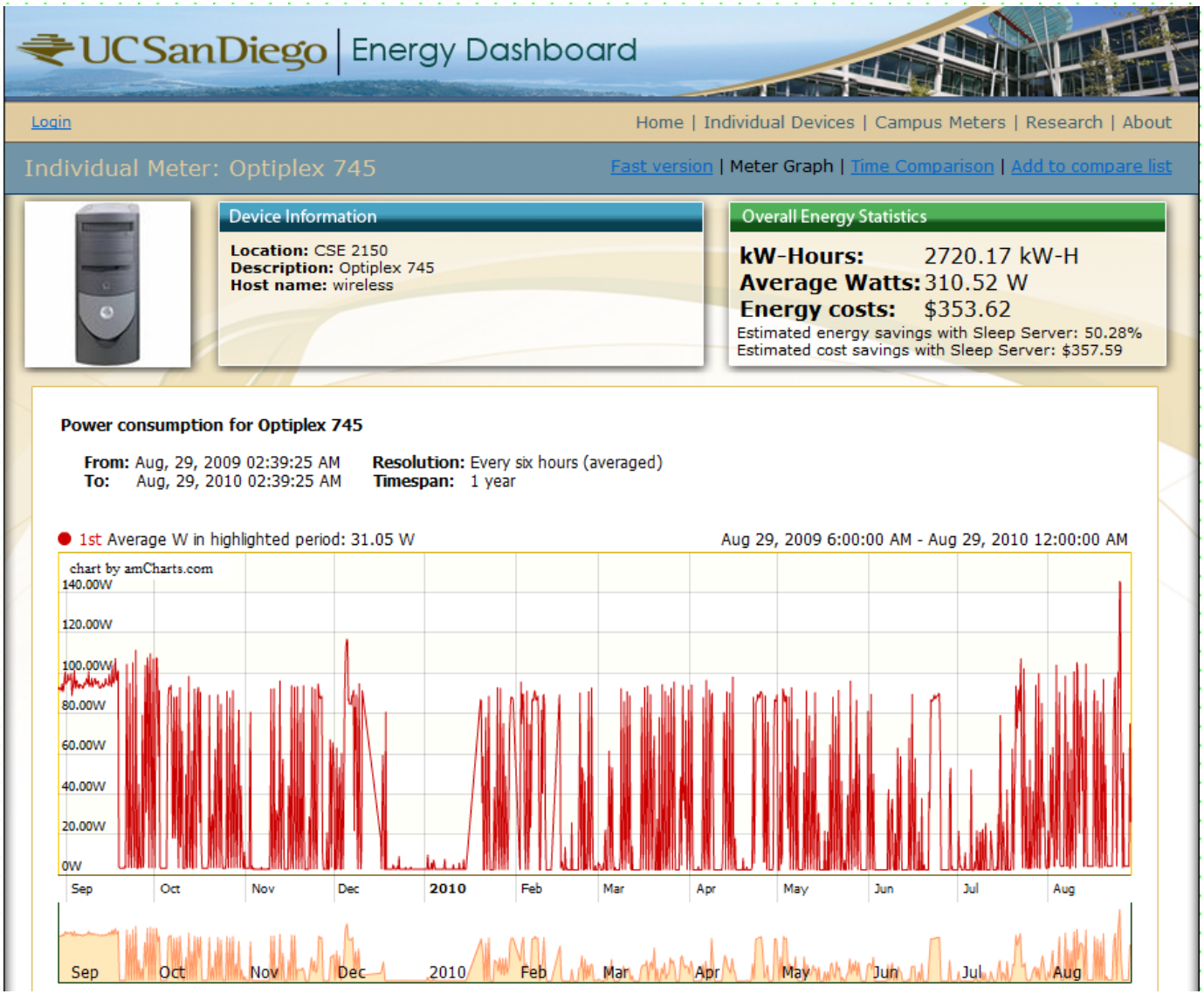




GreenUP: SleepServer + JouleMeter(2)



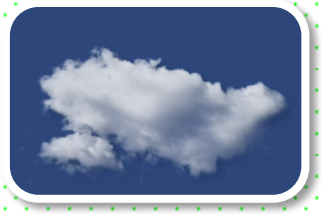
Elsewhere



Courtesy: Yuvraj Agarwal (UCSD)

…….taking on the big beast

Rethinking Business Practices



Online services

- Reduce datacenter workload/energy consumption with cloud services
- Maximize efficiency and sustainability with datacenter operation efficiency

Transfer some of the environmental footprint to a third party data center

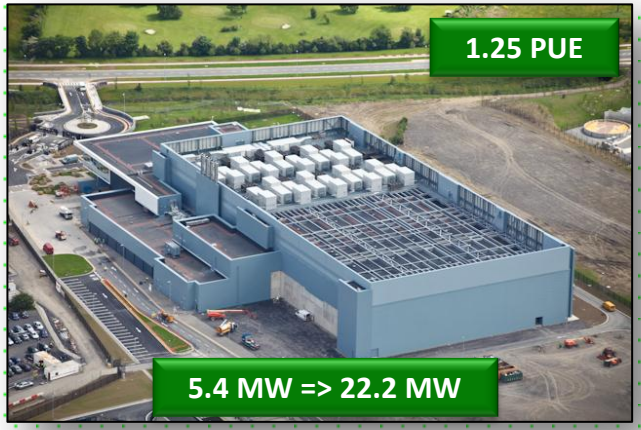
Advantage of scale — odds are DCs used to run your workloads are more efficient than equipment inyour own premises.

Efficiencies of Scale

Microsoft's Quincy, WA, data center uses **100 percent renewable hydropower**.

Microsoft's San Antonio, TX, data center uses **recycled water for cooling & wind as a primary energy source.**

Dublin Data Center



- First mega data center outside US (303K sq. ft & growing)
- European Commission Best Practice Award
- Free air-cooling
  - Chiller-free, air-side economization
  - 1% water use
  - Saves 18 million liters of water/month
  - 50% more efficient
- Reduced waste and carbon Footprint

Chicago Data Center

- Largest known container data center (700,000 sq. ft)
- Scalable & modular, reduced capital costs, construction, packaging, and energy waste
- Water side economizers
- Reduced waste and lower carbon footprint

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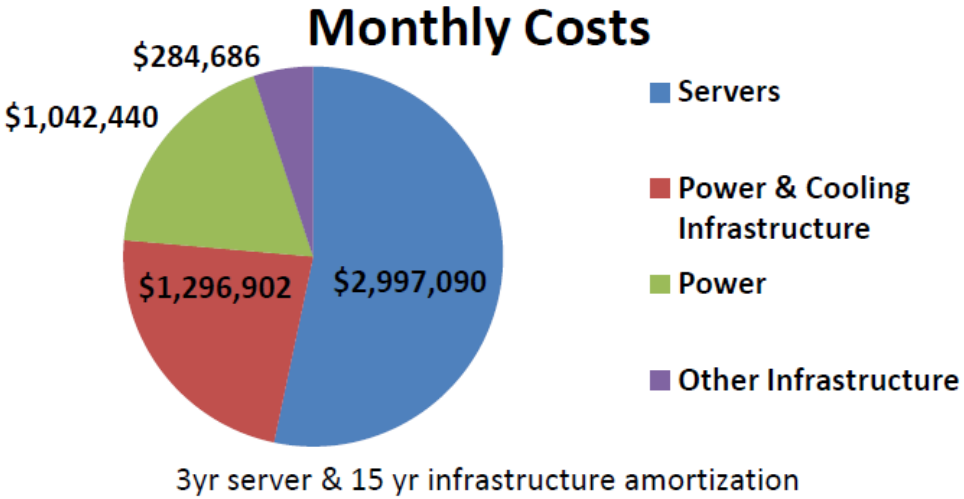
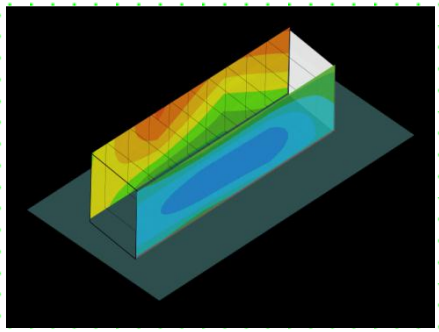
Windows Live SkyDrive
Microsoft Dynamics CRM Online
Microsoft adCenter
Microsoft Office Groove 2007
Connected Services SANDBOX
Enabling Managed Network Mashups
bing
Windows Live Spaces
Microsoft Online Services
Windows Azure
Windows Live Hotmail
Microsoft Live@edu
200 +
Sites and Services
Microsoft Forefront
Microsoft Exchange Online
Microsoft Live Search Maps
Microsoft Silverlight
Windows Live ID
XBOX LIVE
Microsoft Office Communications Online
Live Mesh
Microsoft Office Live Meeting 2007
Microsoft Hosted Messaging & Collaboration
msn
Microsoft SharePoint Online
Microsoft Office Live
Windows Live Messenger
Microsoft game studios
Microsoft HealthVault
Microsoft FlexGo

DC Operation Efficiency



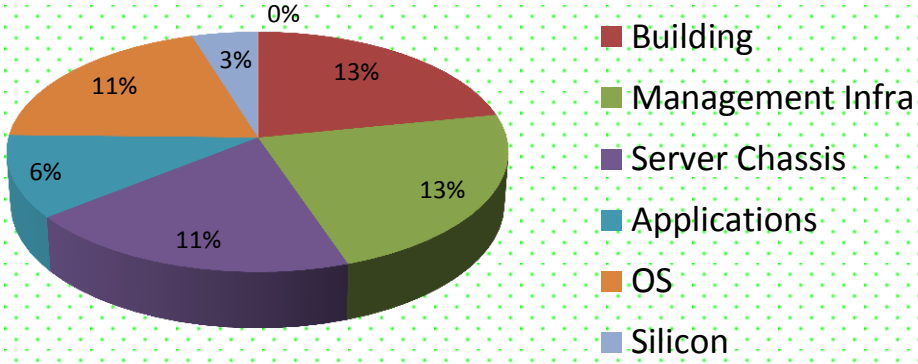
Courtesy: James Hamilton (Amazon)

In poorly designed DC, 50% of the energy goes into Air-conditioning



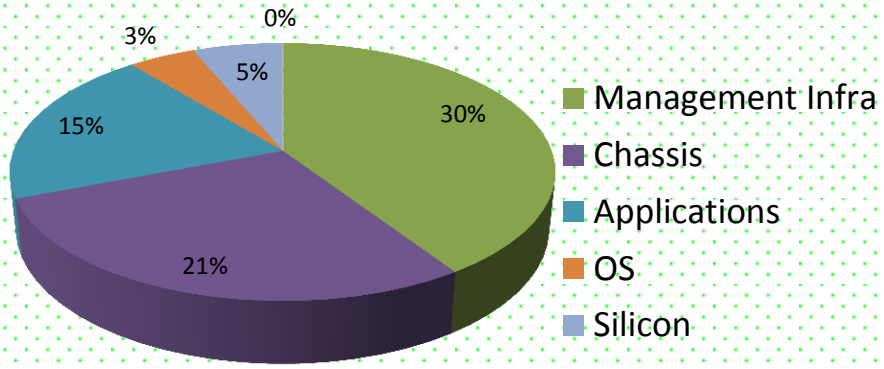
30% of the servers can be turned off for Messenger traffics (NSDI 2008)

Relative Data Center Energy Losses



Source: Microsoft estimates

Relative PC Energy Losses



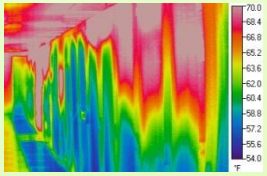
DC Genome System

Courtesy: Jie Liu

Facility layout

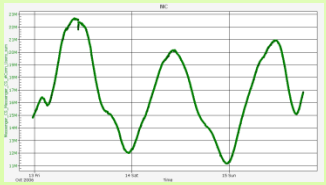
Cooling Systems

Power Systems



Heat Distribution

Server Utilizations



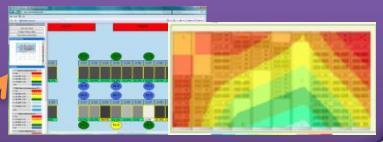
Network Activities

Data Archiving

Data staging

Data analysis & Optimization Tools

DC Genome Explorer



"Genome" (Classes, labels, relations, dynamics, probabilistic models)

Data Center Software Infrastructure

Real-time Monitoring & Control

Change Management

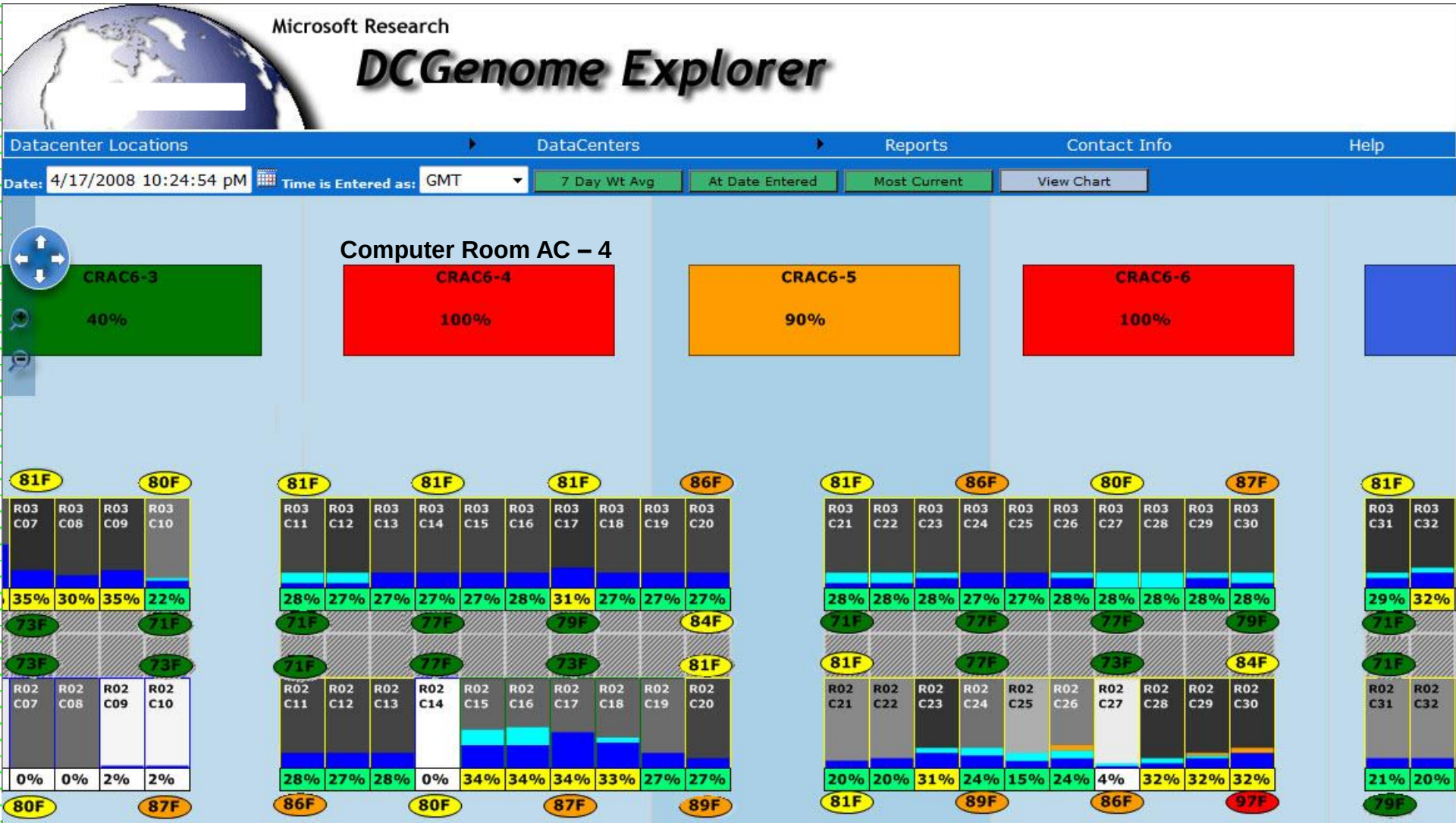
Capacity Planning

Dynamic Server Provisioning

Fault Diagnostics/ Tolerance

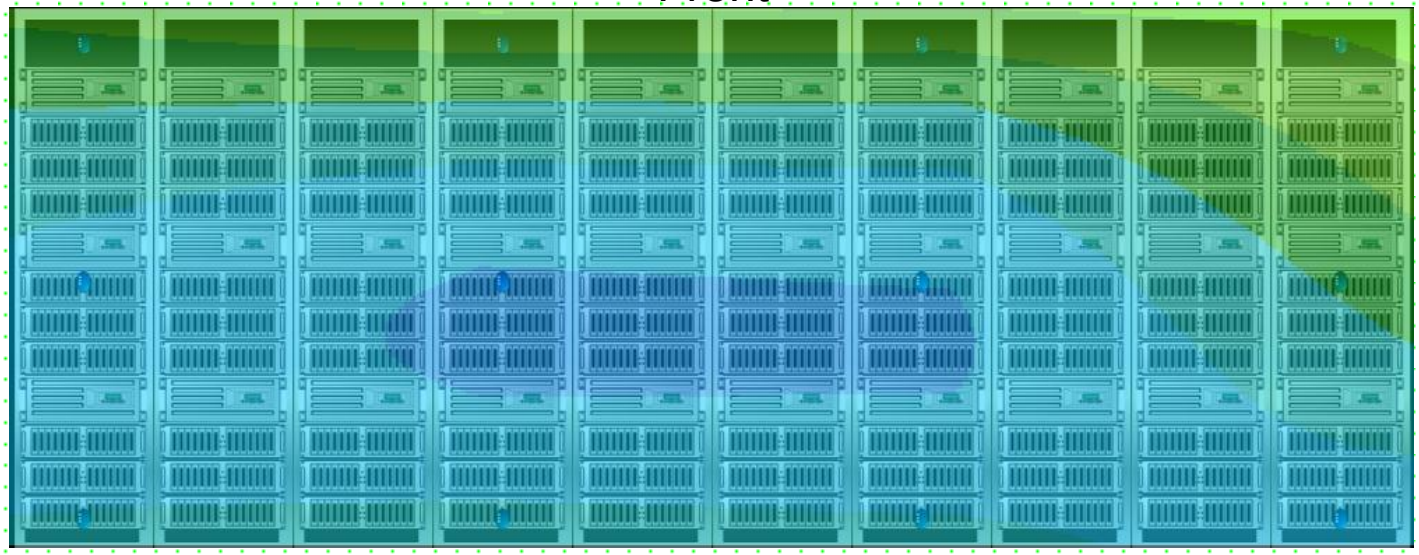
Data Visualization

SenSys 2009

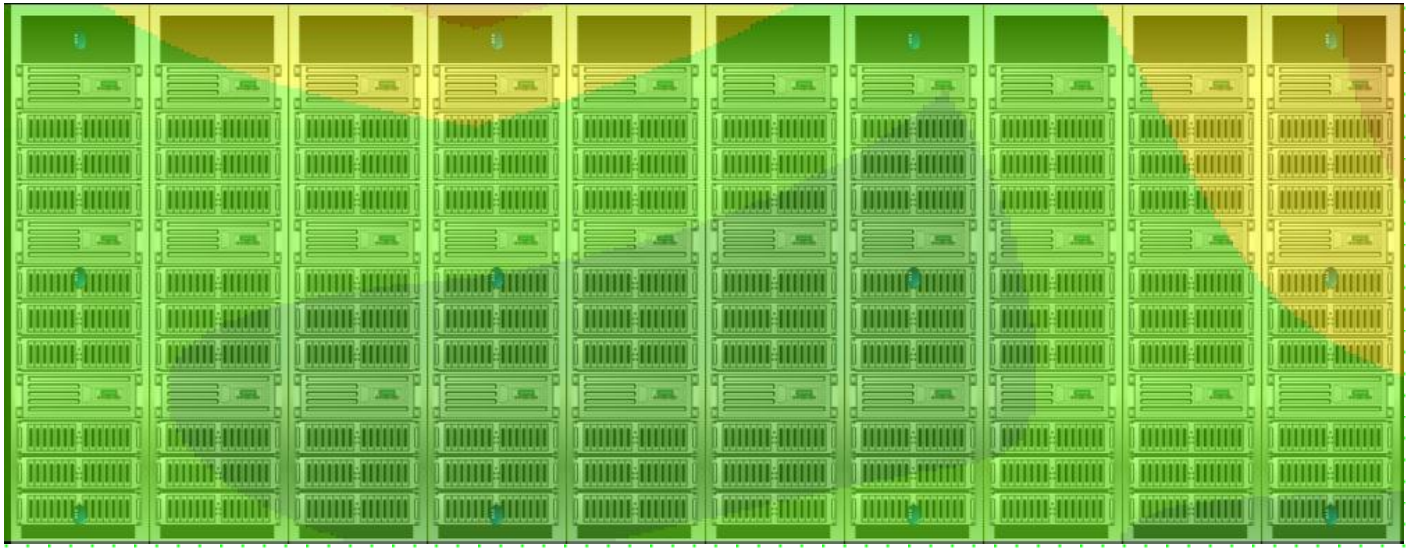


Temperature Contour Maps

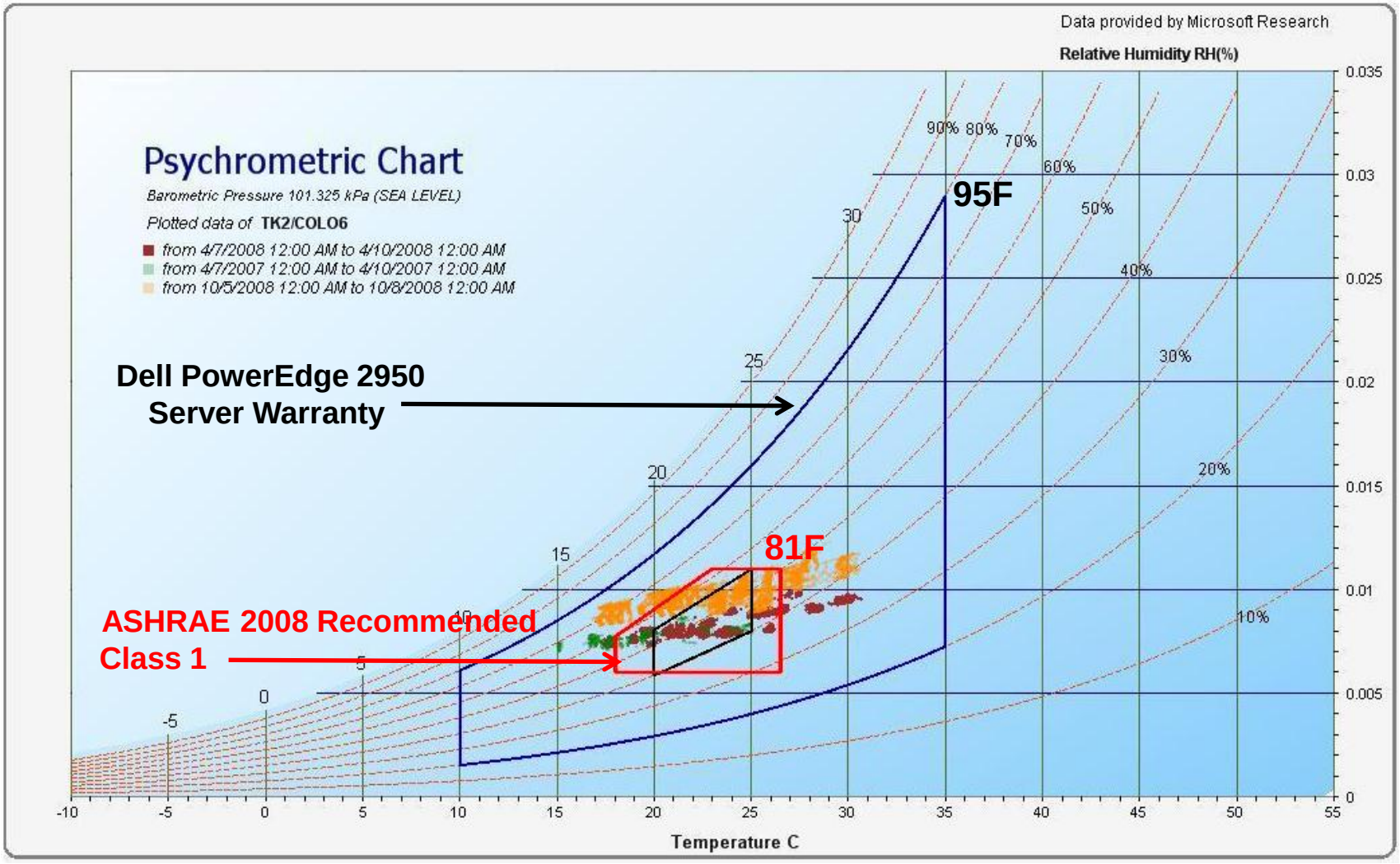
Front



Back



Psychrometric charts



ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers

Efficiency vs. Density

Greater Server Density = Increased Energy/Ft³

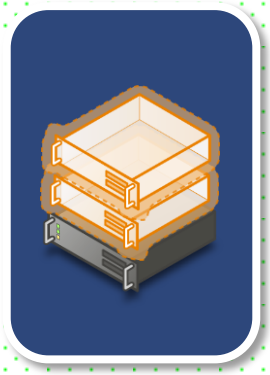
More Trans-actions per Watt

Fewer Watts per Trans-action

Less Power Per Server

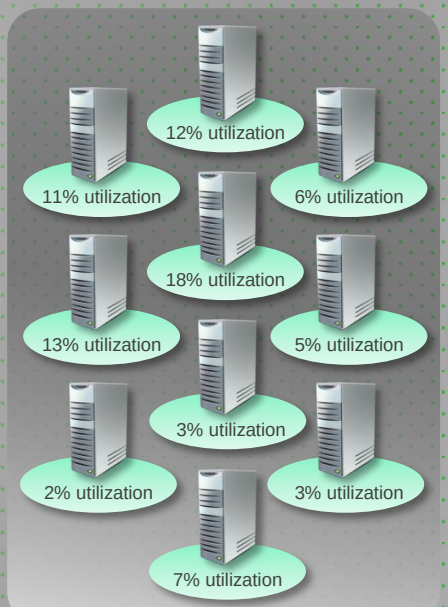
Reducing Energy Demands

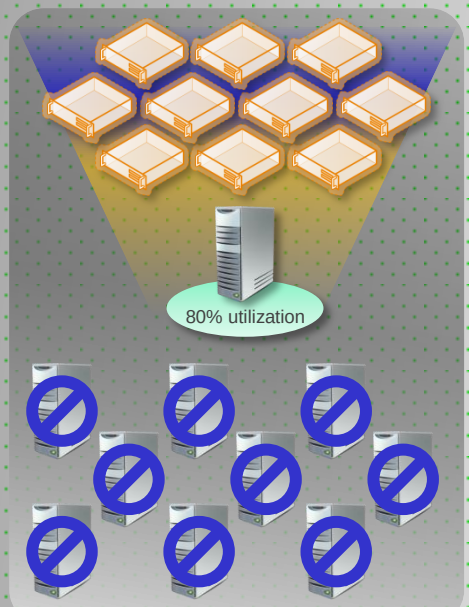
Utilization/Reduce the Number of Physical Machines



Virtualization

Gain multiple virtual servers for the energy/power cost of one physical server

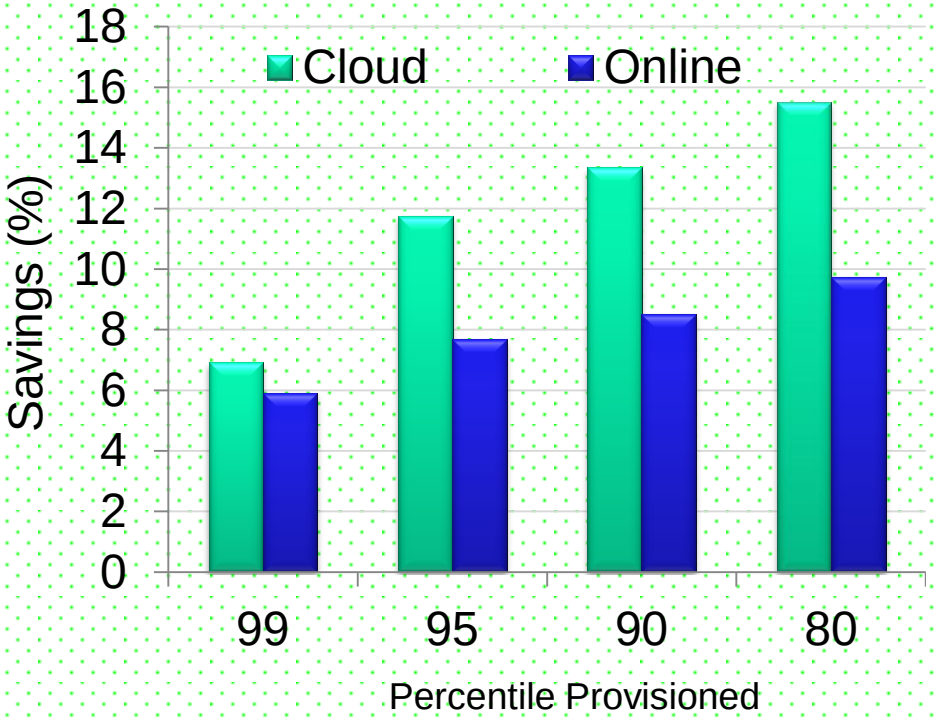


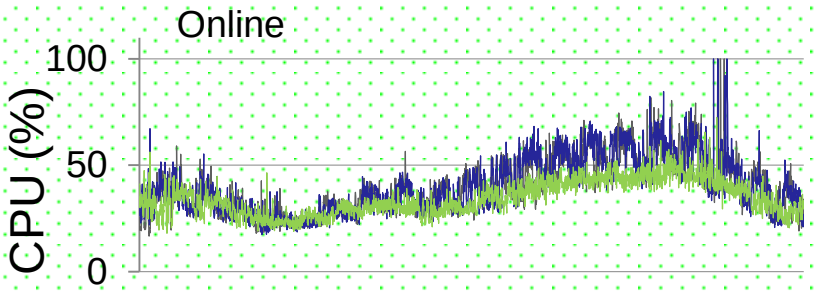


"...the effective use of virtualization can reduce server energy consumption by as much as 82 percent and floor space by as much as 86 percent."

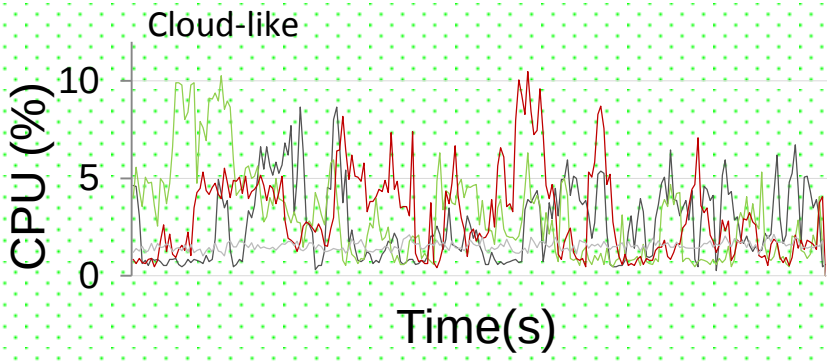
Gartner, Inc., June 2009

Sample Savings from Virtualization





Traces from MSN Messenger



Traces from AdCenter, Creative Asset Management , MSN TV Apollo , Ad Delivery , Shared Services group

Reclaimed Savings

13% to 27%, with benefits of virtualization

Note: Virtualization is a networking problem

.....moving beyond sleeping

...and beyond Data centers

Rethinking Business Practices

Reduce Travel, Commuting, and Office Space Requirements

Travel & Commuting

- 62% of the companies are already reducing their business travel footprint + 24% are developing plans to do so.
- 89% expect they will want to fly less over the next 10 years.

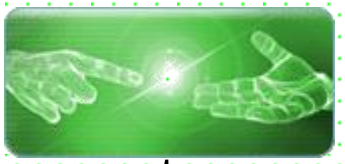
Travelling Light, U.K. WWF, 2008

Unified communications	**Replace travel and commuting for meetings or training with Web/ videoconferencing**
Collaboration	**Support tele- and remote workers with portals, social computing, and document workspaces**

"... if a significant number of people worked from home more than three days a week, this could lead to energy savings of 20-50%..."

The Climate Group, 2008

Telepresence



A videoconferencing experience that creates the illusion that the remote participants are in the same room with you.

Videoconferencing has the potential to replace up to 30 percent of business travel
The Climate Group (SMART 2020, June 2008)

Cisco Telepresence $299k

Tandberg Experia $225k

HP Halo $425k + $18k/mo

Polycom RPX210M $269k + $18.5k/mo

MS Personal Telepresence Station

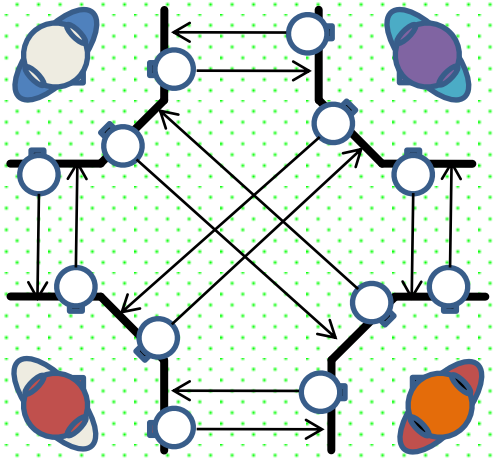
Replicate experience people enjoy in face-to-face meeting

- Dedicated camera-display-speaker for remote stand-in
- Tailored to a single person → Correct spatial cues

Prototypes

video

Full Mesh Geometry

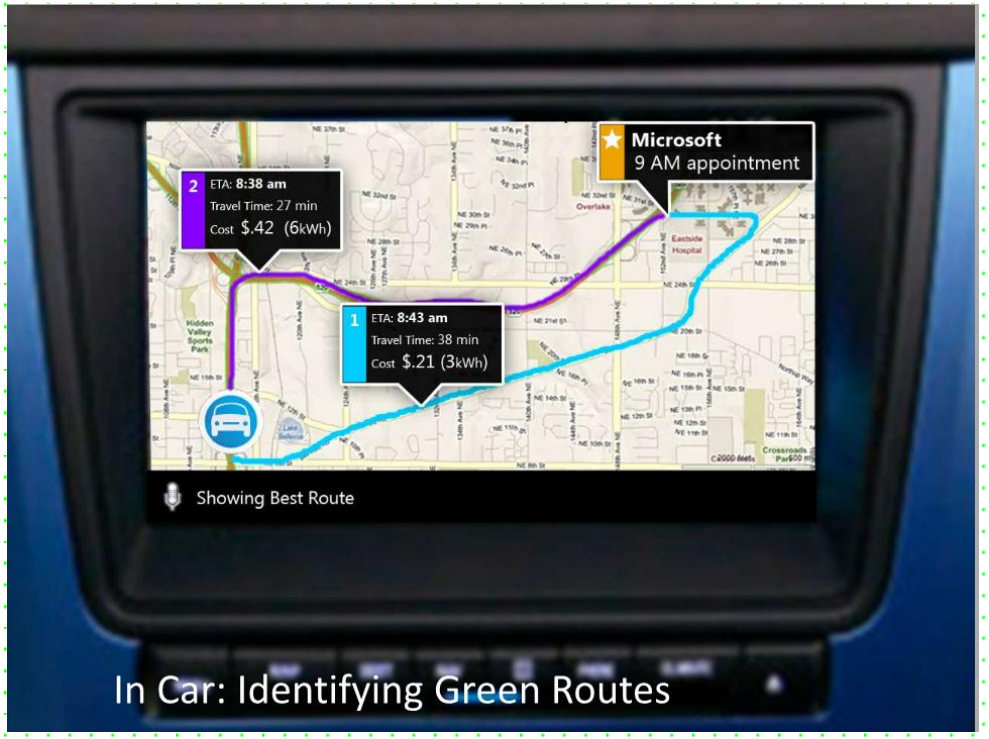


Courtesy: Zhengyou Zhang

IT for Greening

Traffic congestion → **time** & **fuel** waste **(Courtesy: Mario Gerla)**

- Air **pollution** caused by vehicles reduces city livability
- Existing traffic control through "green wave" is not enough
- Nitric Oxide (NO) concentration exhibits high spatial and temporal variability (Environmental Health Perspectives, Nov 2009)
  - How to implement dynamic congestion and pollution control?



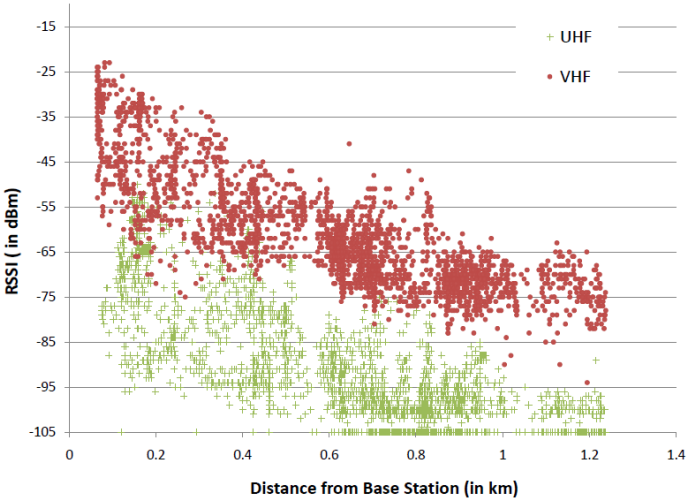
In collaboration with RICE

Greening with TV Whitespaces

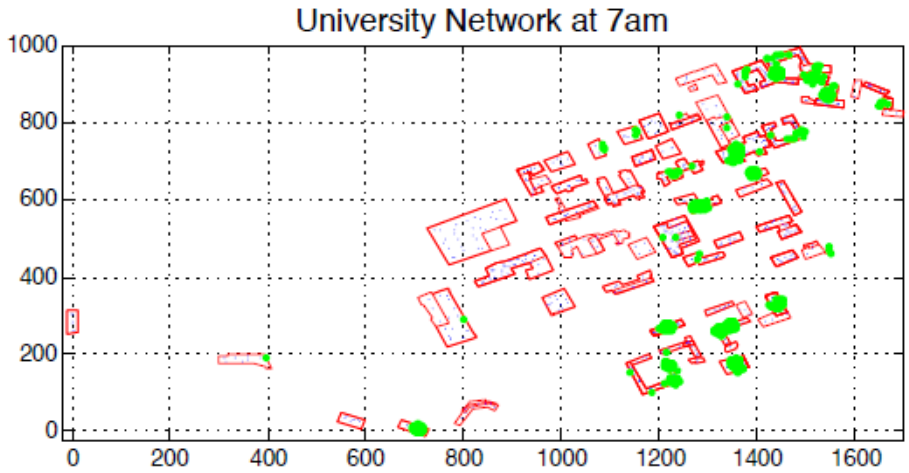
MSR's Redmond Campus

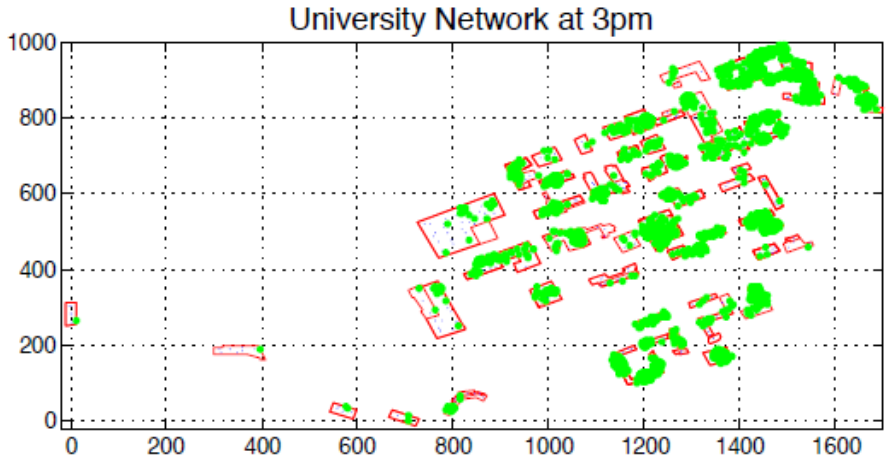
***Route taken by the shuttle* (0.95 miles x 0.75 miles)**

~4x range compared to 2.4 GHz (Wi-Fi) with same transmit power and receiver sensitivity



Raw received power at different Distances from the transmitter





Victor Bahl, SIGCOMM Green Networking Workshop 2010

Total power consumption of DoCoMo's Network is 2.4 TWh, that is 5%of Total IT Energy Consumption in Japan. Approx. 126 Wh/day/docomo-user

- Atsushi Murase, Managing Director NTT DoCoMo.

Mobile Networks occupy 10% of total IT Consumption & 0.1% of total energy consumption in Japan.

- Study Group on ICT , March 2007

Let's talk about marrying the mobile user to the cloud?

http://research.microsoft.com/hawaii

Final Remarks

- Look at the problem holistically, lots of opportunities availability
  - Silicon, OS, applications, hardware packaging, buildings etc.
- Greatest savings come from sleeping (works for cell phones, homes, enterprises, datacenters)
  - My mother taught me "Don't Waste" -> applies to energy too!
- Faster adoption when technology saves significant money
  - Users adopt it if it doesn't change their lifestyle
    - People want to be able to access their machines whenever they want without modifying their own behavior
- Transparency can change habits & is necessary for improving architecture & design
- Offloading computations to the cloud by SmartPhones has energy implications that still need to be quantified

It's the Right Thing to do & It's Good Business

"Green IT has reached critical mass. Virtually **all the companies we surveyed (97 percent)** are discussing their **Green strategy**."

"Green IT Report Regional Data – United States and Canada: Survey Results," Symantec, May 2009

"Enterprise PCs are **wasting money**. Far too many organizations leave economic and environmental value on the table by not **reducing PC-related energy costs**."

"How Much Money Are Your Idle PCs Wasting?," Forrester Research, Inc., December 2008

"Transformation in the way people and businesses use technology could **reduce annual man-made global emissions by 15 per cent** by 2020 and deliver energy efficiency savings to global businesses of **over EUR 500 billion** [GBP 400 billion/USD 800 billion]."

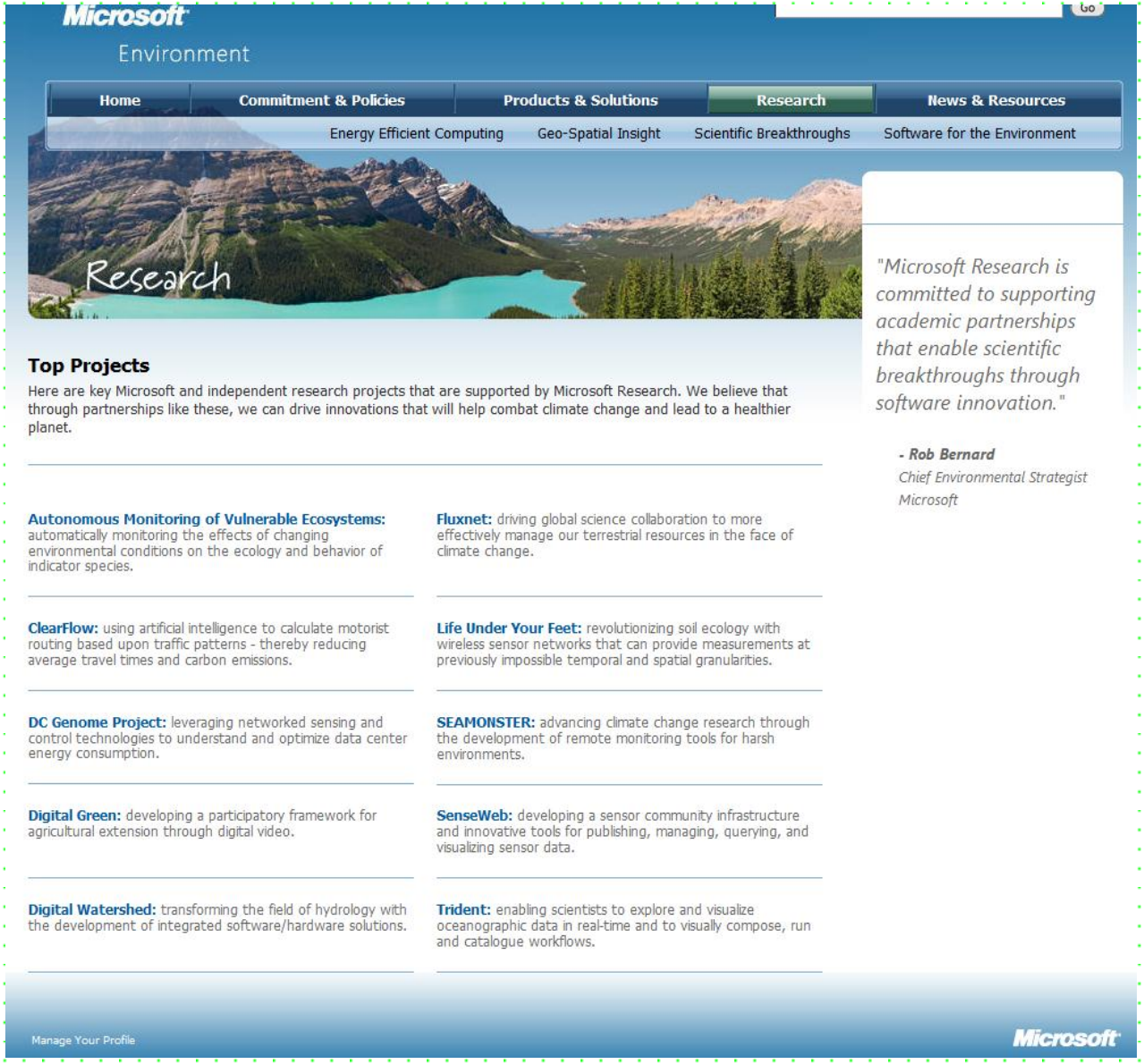
"SMART 2020: Enabling the Low Carbon Economy in the Information Age," The Climate Group, June 2008

"IT's role will increasingly be about applying the technology to create **more-energy-efficient, less-carbon-intensive business models**, enterprises, value chains, products and services with reduced environmental impact."

"User Survey Analysis: Sustainability and Green IT, Worldwide, 2009," Gartner, Inc., April 2009

Some MSR supported Projects with Academia

http://www.microsoft.com/environment/research/



Thanks

http://research.microsoft.com/nrg/