Toward the EverGreen Future

A software perspective

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An IT Perspective

Save $$$

Our Philosophy: When not working, go to sleep

- Handhelds (*UCOM/WoW, Cell2Notify*)
- Home PC / Home Servers (*Somniloquy)*
- Enterprise Desktop (*Green Up, LiteGreen*)
- Datacenters (*DC Genome*)

Observations

- Transparency (JouleMeter)

som-nilo-quy (noun): The act or habit of talking while asleep

Home & Office Computing

Battery Powered Computers

"Wall Powered" Computers

Lenovo X61 laptop
Power: 0.74W (sleep) to **16W** (active)

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 usage* (NSDI 2009)

- Almost all desktop machines in MSR are left on after work hours

Enterprise & Datacenter Computing

Source: US Dept. of Energy
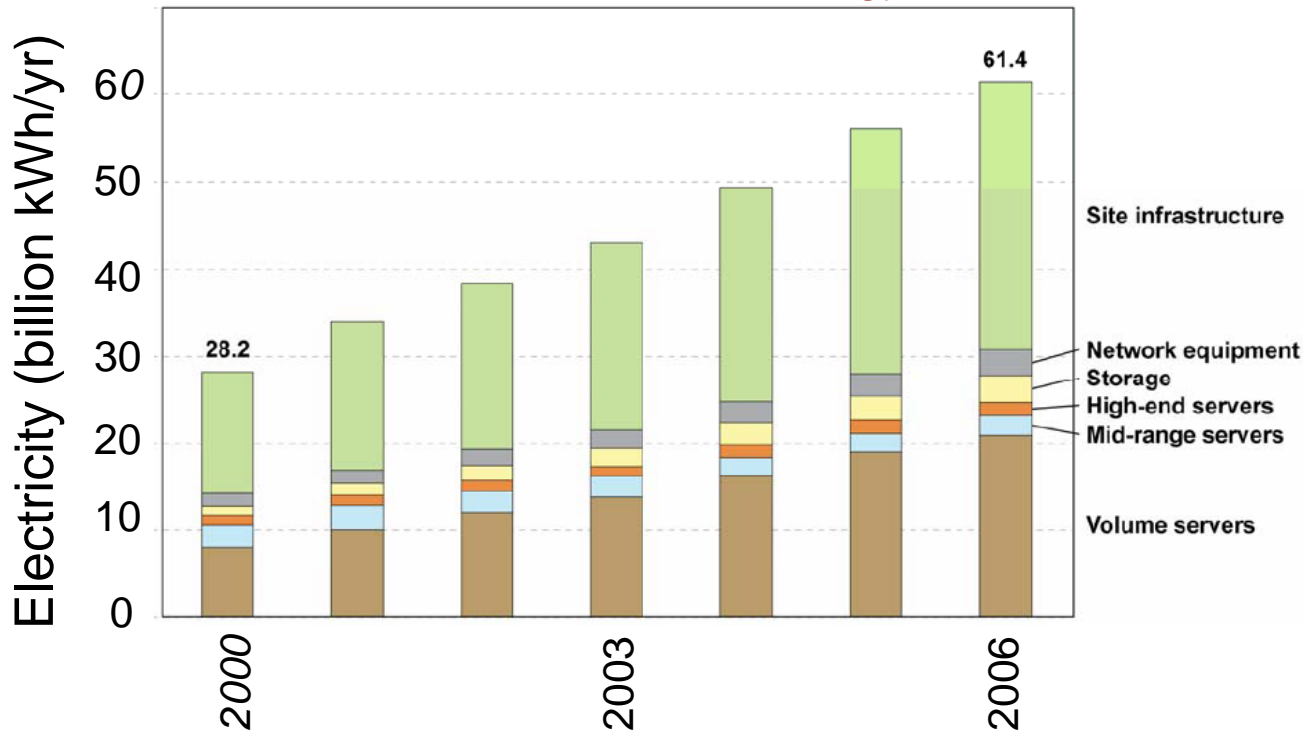
E. Cost: $4.5b
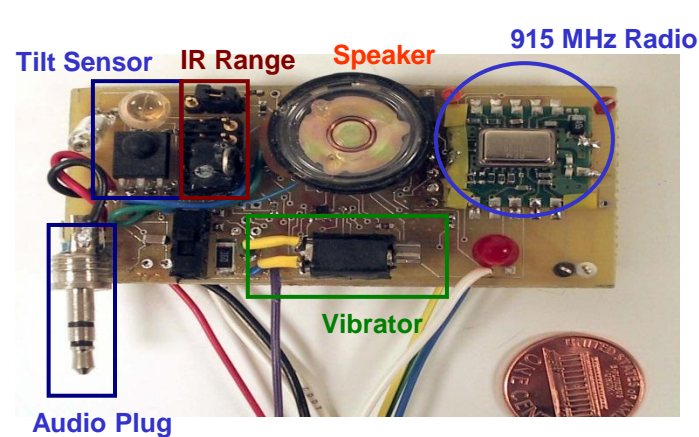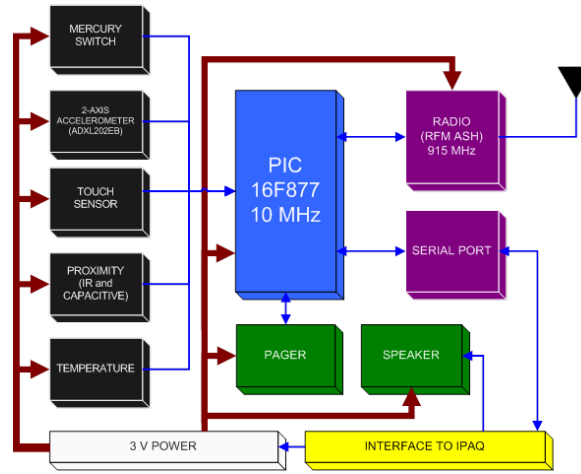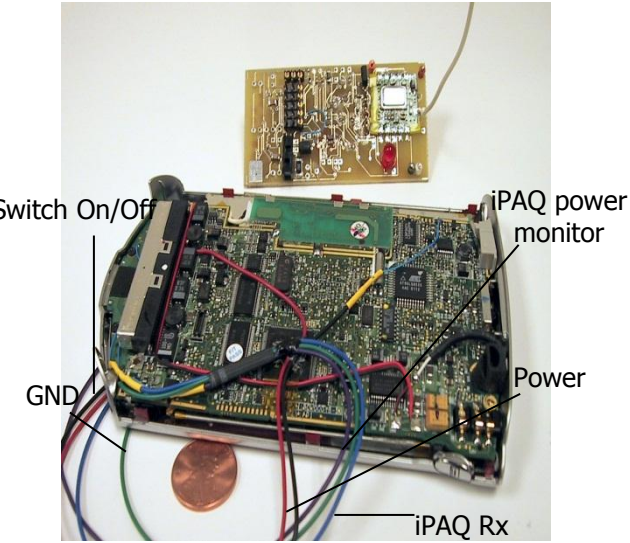Energy usage growing at 14% yearly

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)
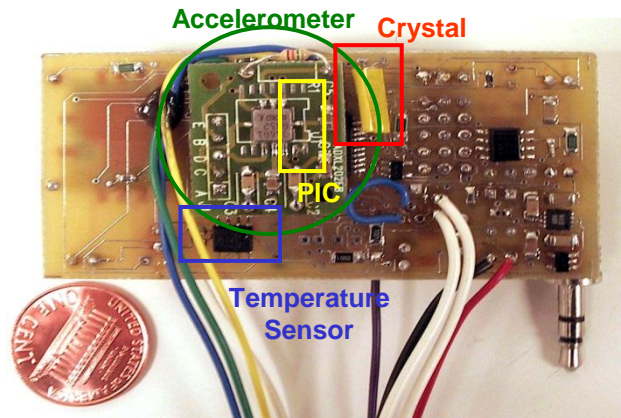
In the beginning….

SmartPhone Energy Management

Wake on Wireless (2001-02)
LPR to a Trigger Wakeups

Switch On/Off
iPAQ power monitor
GND
Power
iPAQ Rx

Block diagram:
- MERCURY SWITCH
- 2-AXIS ACCELEROMETER (ADXL202EB)
- TOUCH SENSOR
- PROXIMITY (IR and CAPACITIVE)
- TEMPERATURE
- PIC 16F877 10 MHz
- RADIO (RFM ASH) 915 MHz
- SERIAL PORT
- PAGER
- SPEAKER
- 3 V POWER
- INTERFACE TO IPAQ

Front View
- Tilt Sensor
- IR Range
- Speaker
- 915 MHz Radio
- Audio Plug
- Vibrator

Back View
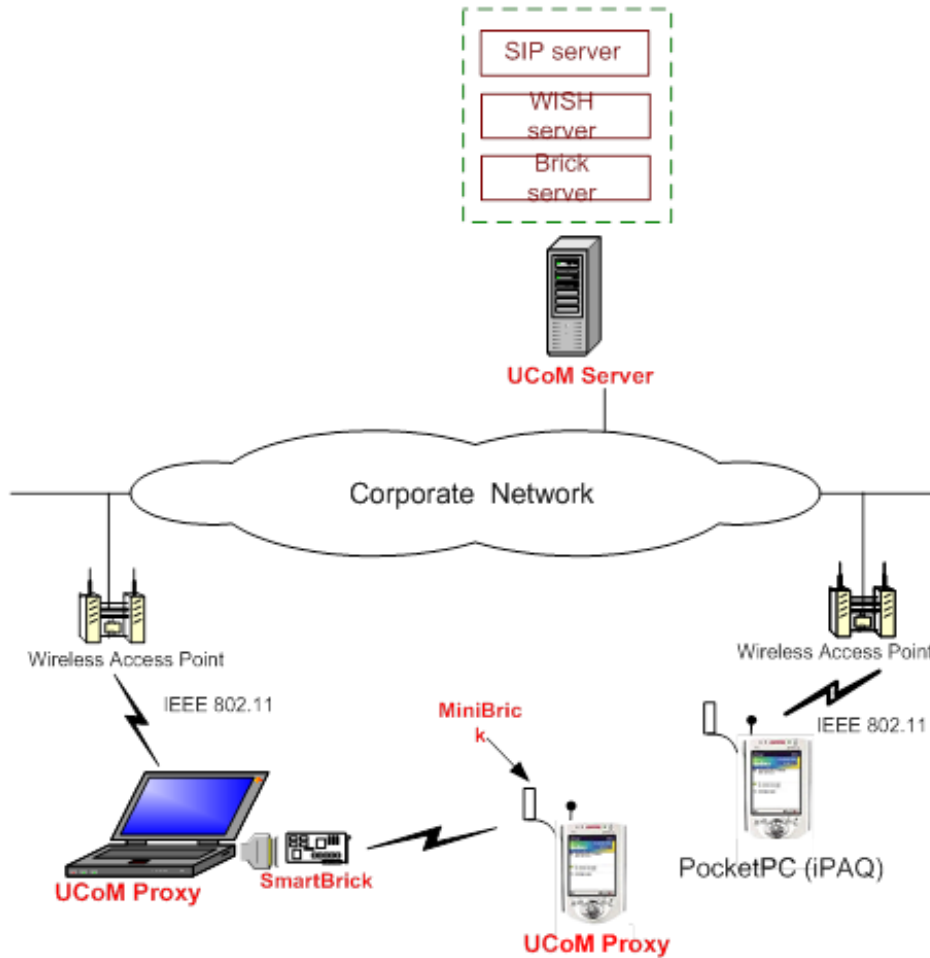- Accelerometer
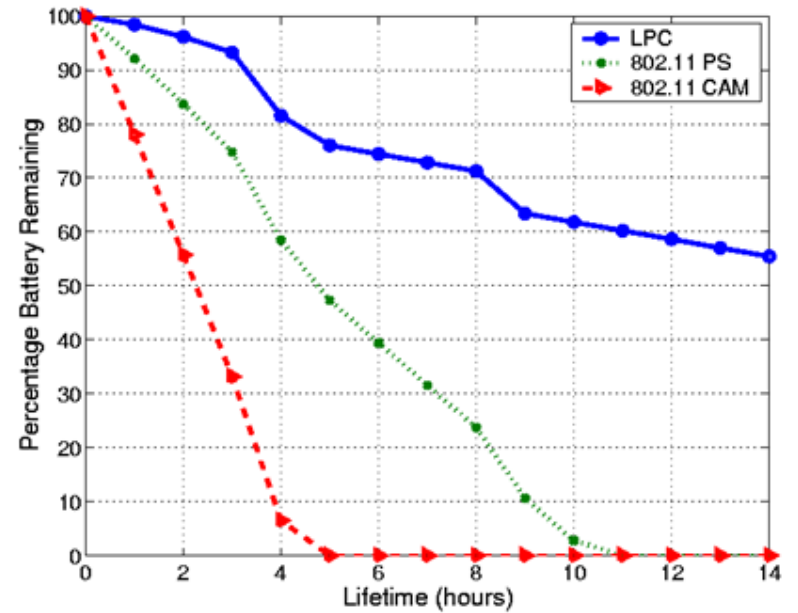- Crystal
- PIC
- Temperature Sensor

Wake on Wireless with LPR
Energy Saving

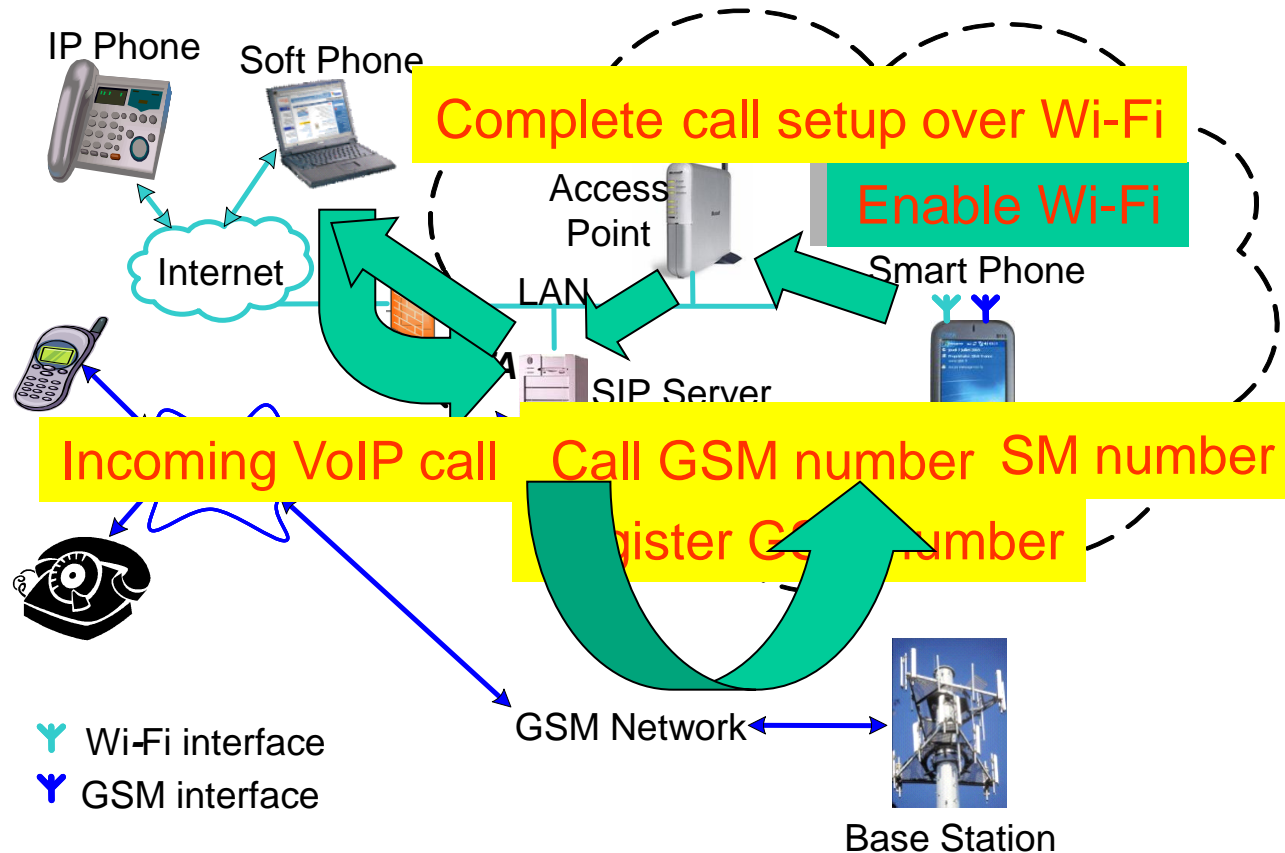2001-02

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

IP Phone   Soft Phone

Internet

Access Point

LAN

SIP Server

Smart Phone

Complete call setup over Wi-Fi

Enable Wi-Fi

Incoming VoIP call   **Call GSM number**   **SM number**

Register GSM number

Wi-Fi interface
GSM interface

GSM Network

Base Station

Security: SIP Server uses different caller ID every time

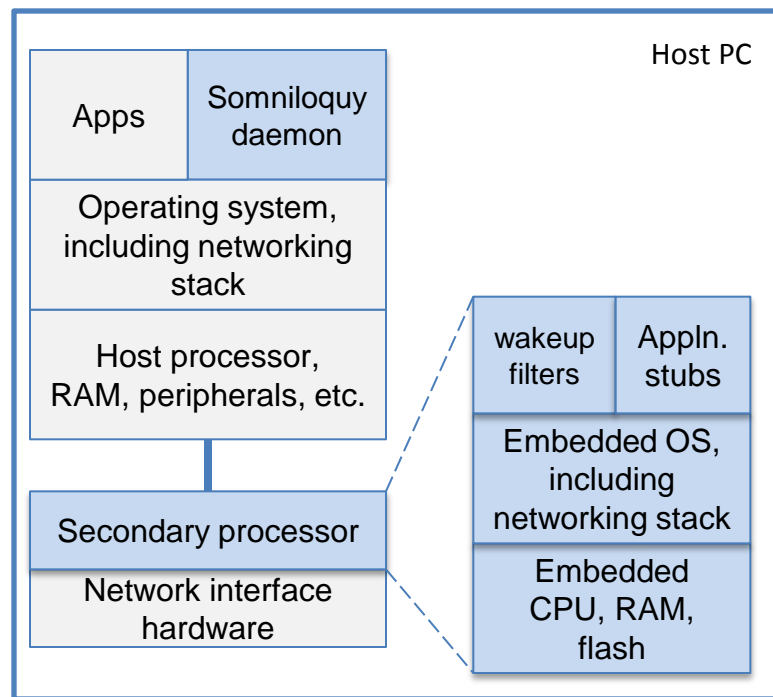# Wake on Wireless with Cell2Notify

Energy Savings
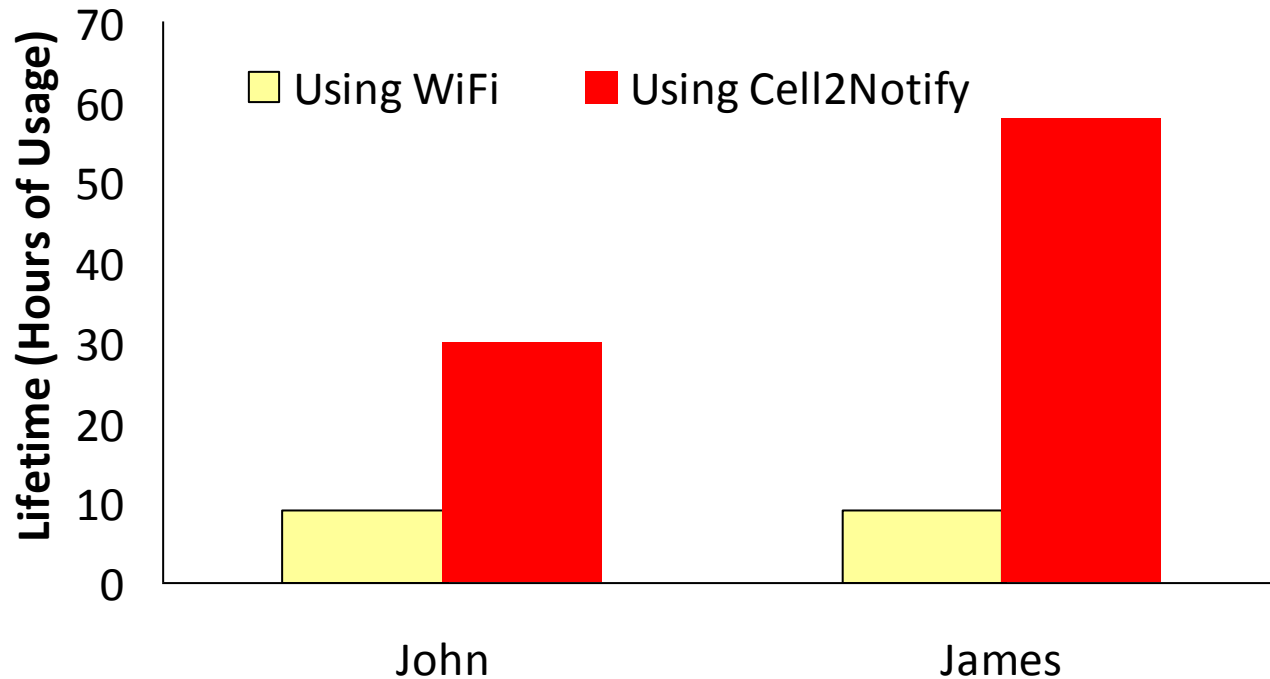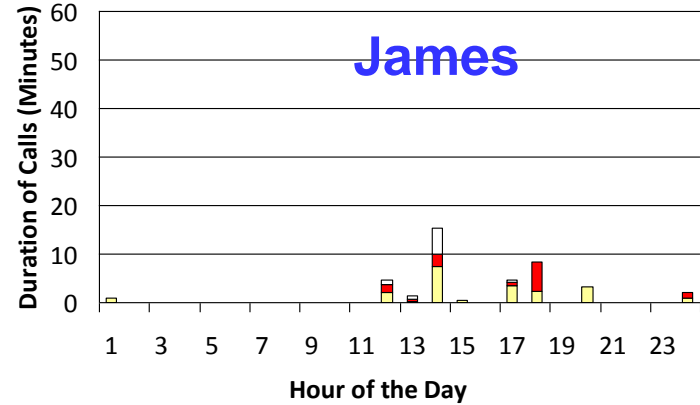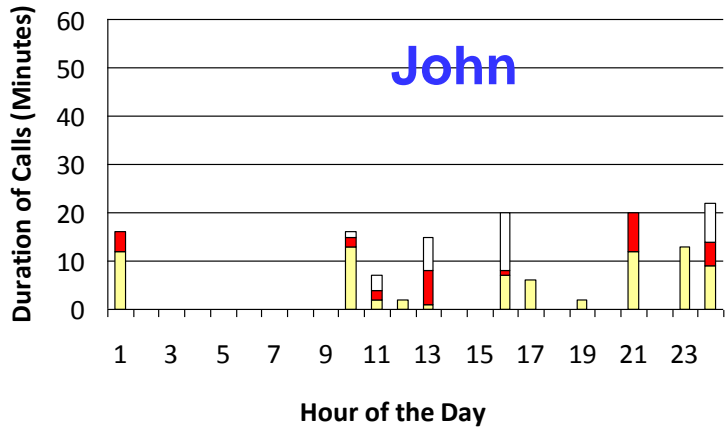
… extending the concept of sleeping to home
& enterprise

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: 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"

Host PC

| Apps | Somniloquy daemon |

Operating system, including networking stack

Host processor, RAM, peripherals, etc.

Secondary processor

Network interface hardware

| wakeup filters | Appln. stubs |

Embedded OS, including networking stack

Embedded CPU, RAM, flash

Somniloquy

USB Interface
(Wake up Host + Status + Debug)

USB Interface
(power + USBNet*)*

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

SD Storage

Processor
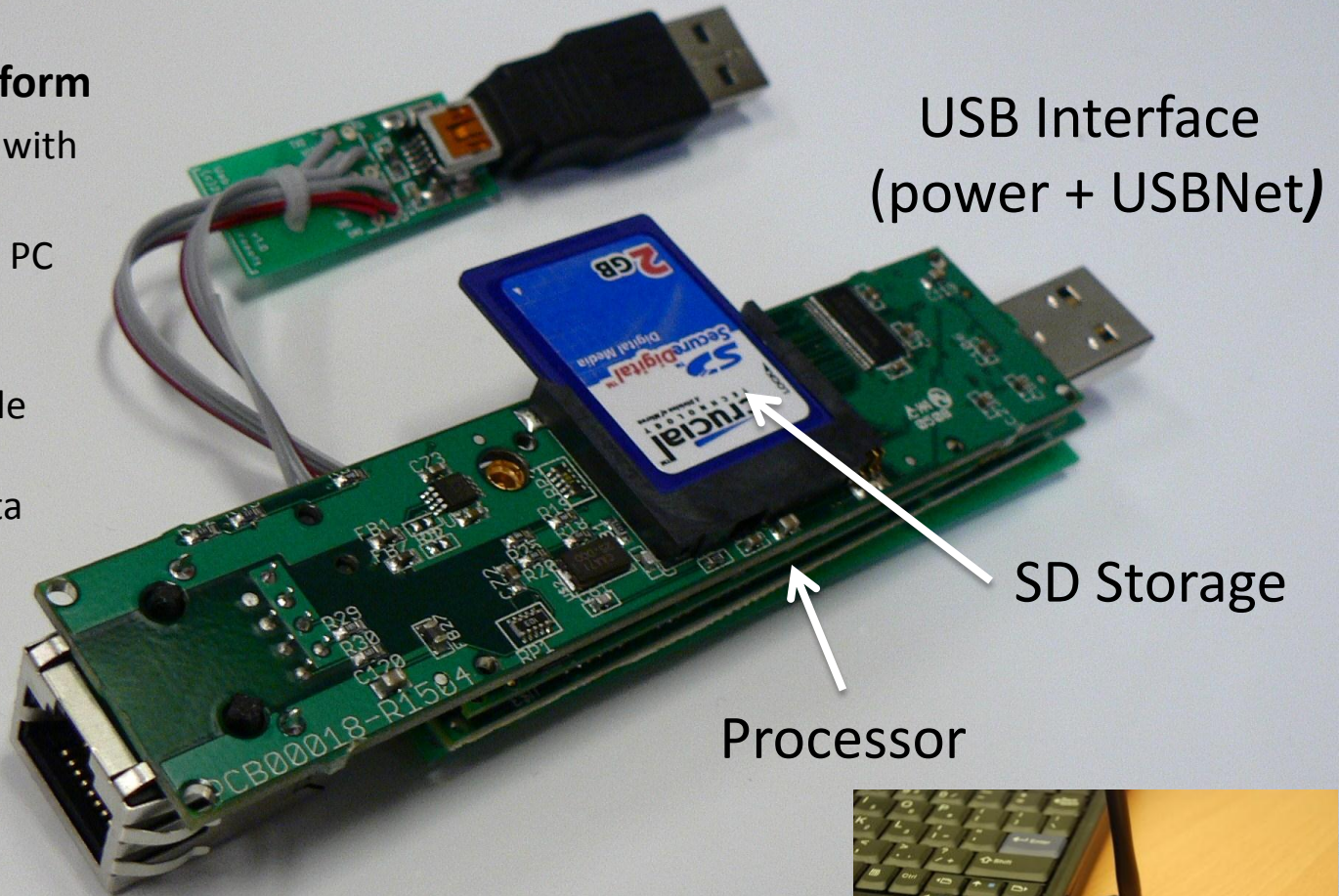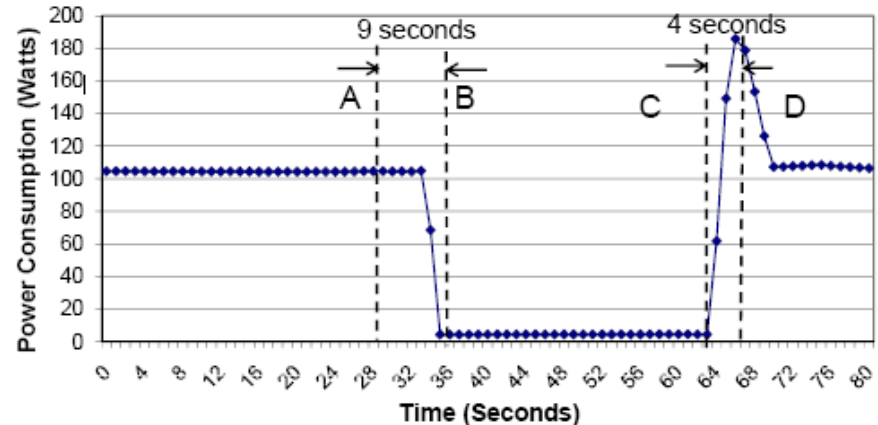
100Mbps Ethernet Interface

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**
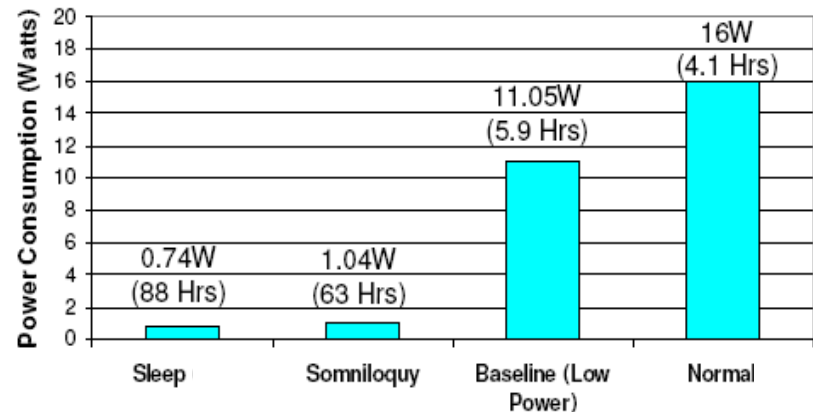- **US $56 savings, 378 kg CO_2**

For Laptops

– Power drops from >11W to 1W,

- **Battery life increases from <6 hours to >60 hours**

– Provides functionality of the "Baseline" state
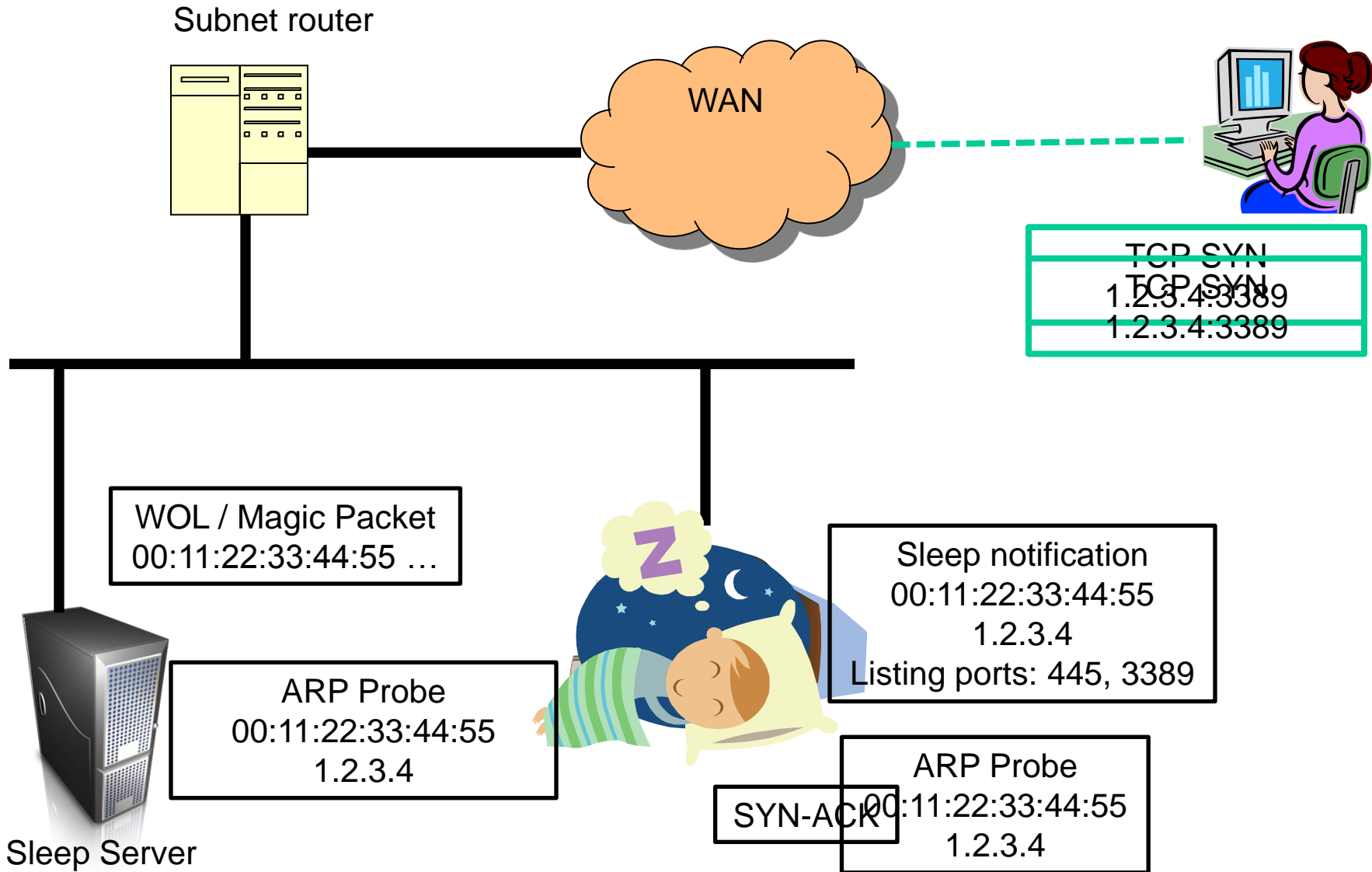
- Power consumption similar to "Sleep" state

IBM X60 Power Consumption

SleepProxy: A Software-only Enterprise Solution

Subnet router

WAN

TCP SYN
1.2.3.4:3389
TCP SYN
1.2.3.4:3389

WOL / Magic Packet
00:11:22:33:44:55 …

Sleep notification
00:11:22:33:44:55
1.2.3.4
Listing ports: 445, 3389

ARP Probe
00:11:22:33:44:55
1.2.3.4

ARP Probe
00:11:22:33:44:55
1.2.3.4

SYN-ACK

Sleep Server

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Typical machine sleeps > 40% of the time

LiteGreen: A VM Based Solution
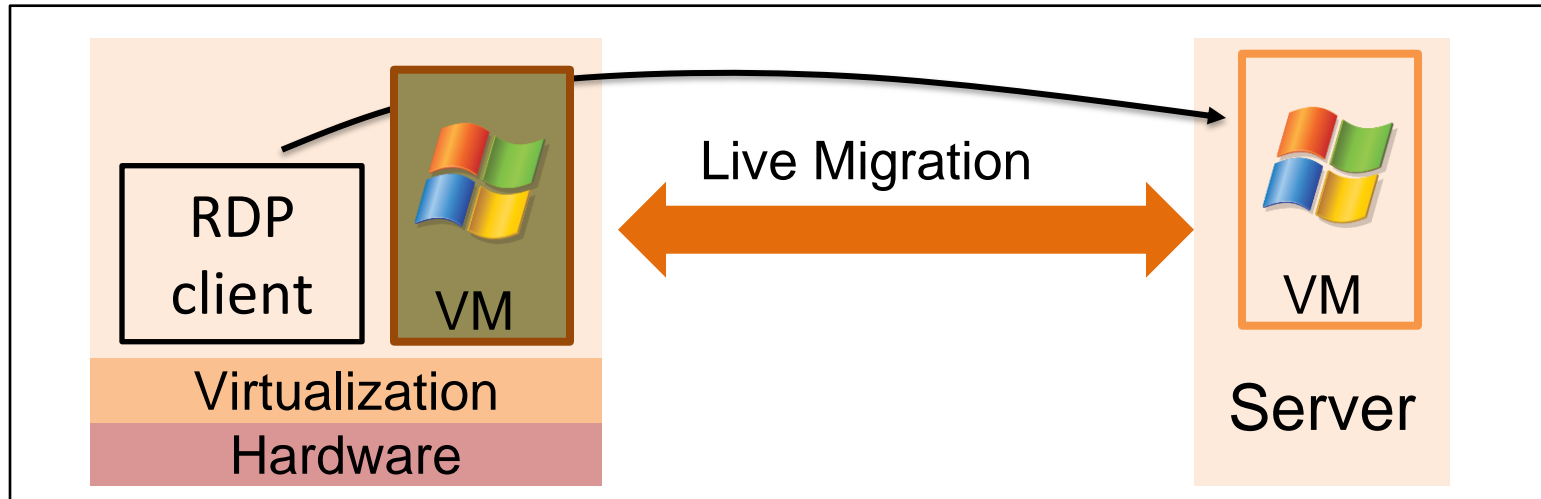
- Prevalence of short idle periods

- Virtualization + Migration to save energy during short and long idle periods while avoiding user disruption

- LiteGreen can help save 60-72% of desktop energy
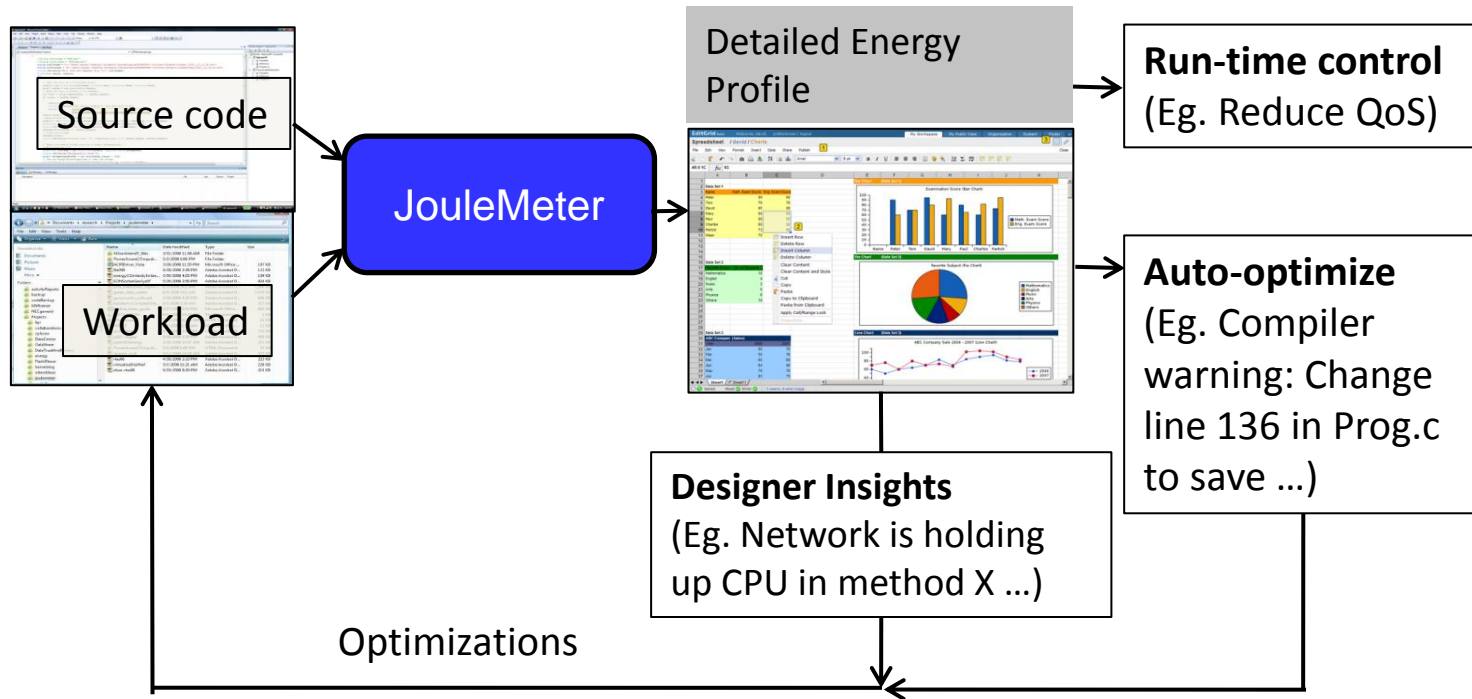
Joulemeter: Providing Transparency

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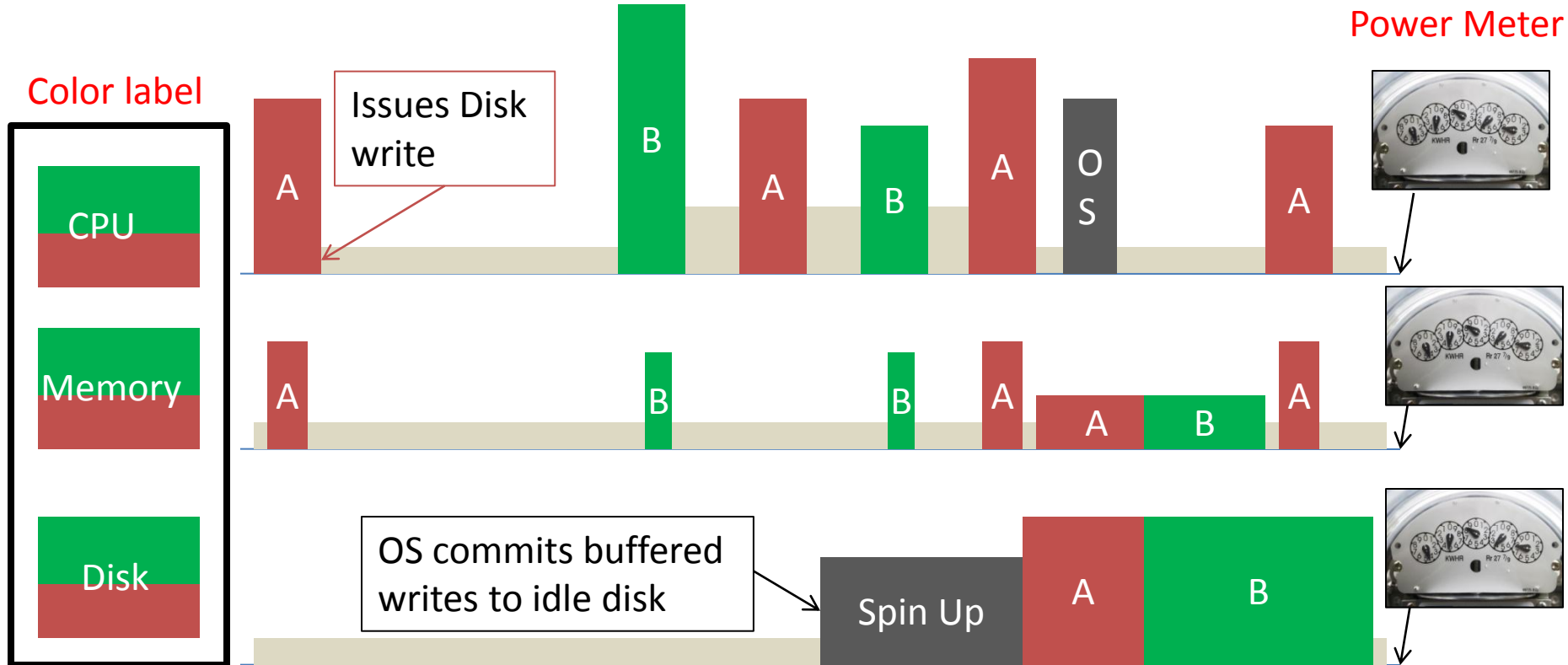
- Energy(App A) = Σ (red rectangles)
  - Other components: Network, GPU, … (Not in current version)

Fine Grained Visibility

Measure application energy usage in depth

Run-time control
(Eg. Reduce QoS)

Detailed Energy Profile

JouleMeter

Source code

Workload

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

GreenNotifier

POWER CONSUMPTION		
Current	139.005	W
Average	139.897	W

STATISTICS SINCE INSTALL
AT 10/29/2009 3:15:55 PM

Time Awake	16.662	hours
Estimated Consumption	2.331	kWh
	14.106	cubic ft of CO2
Time Slept	74.792	hours
Estimated Savings	10.463	kWh
	63.32	cubic ft of CO2

Minimize to tray

…About transparency, take on the big beast
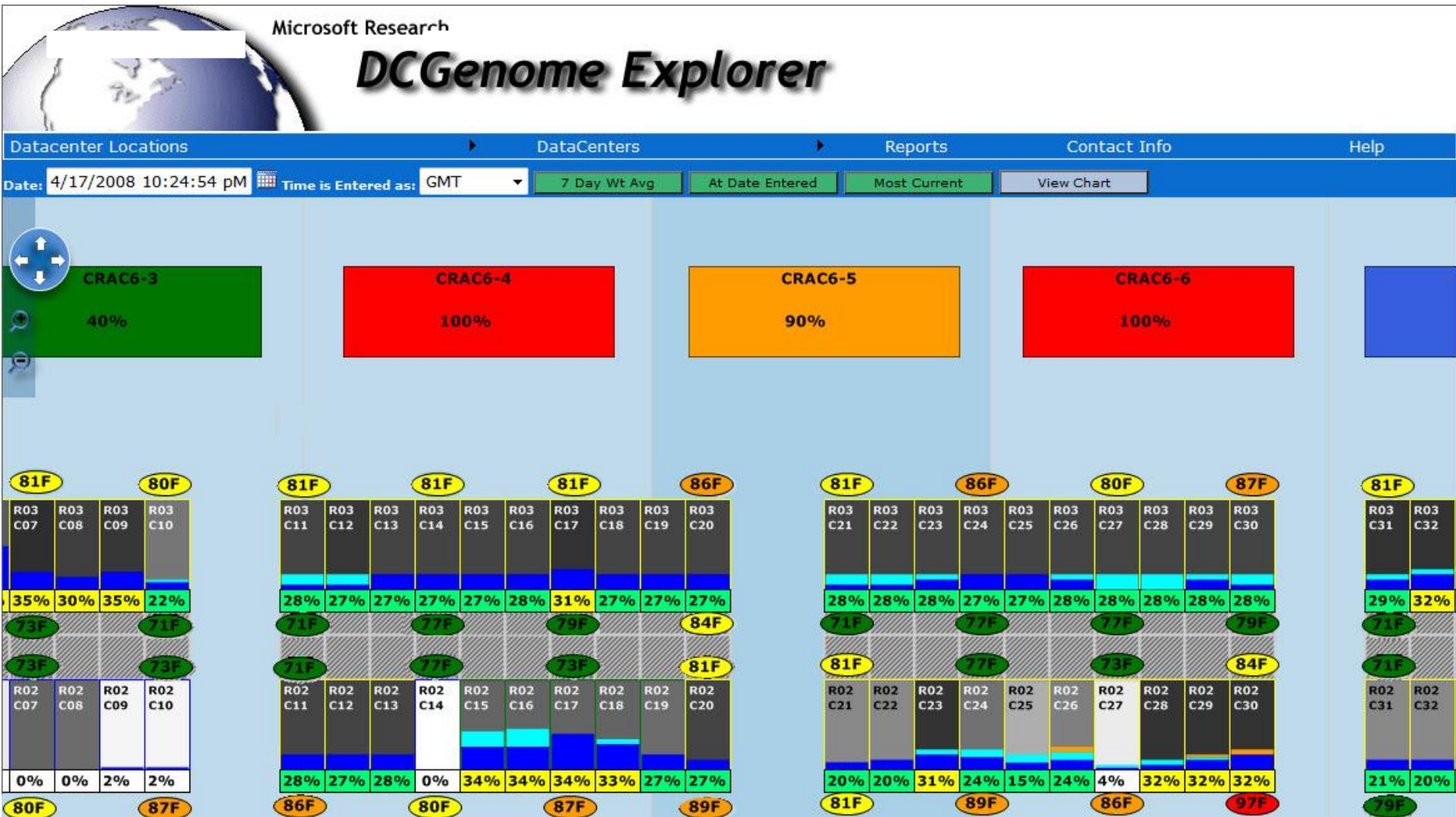
Datacenter Energy Management
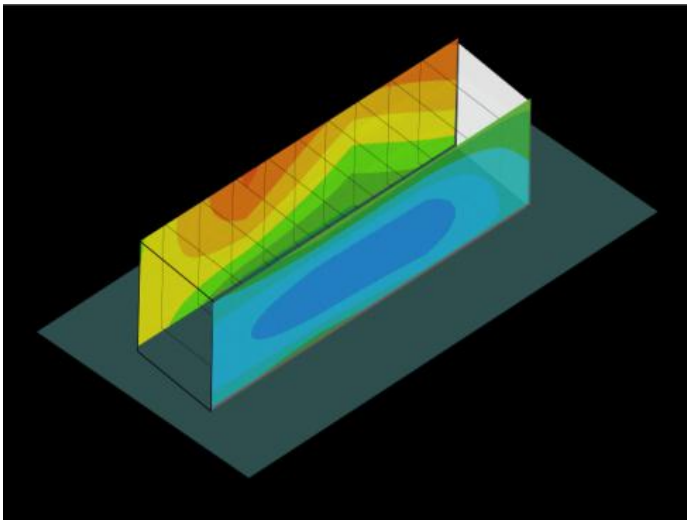
In poorly designed DC, 50% of the
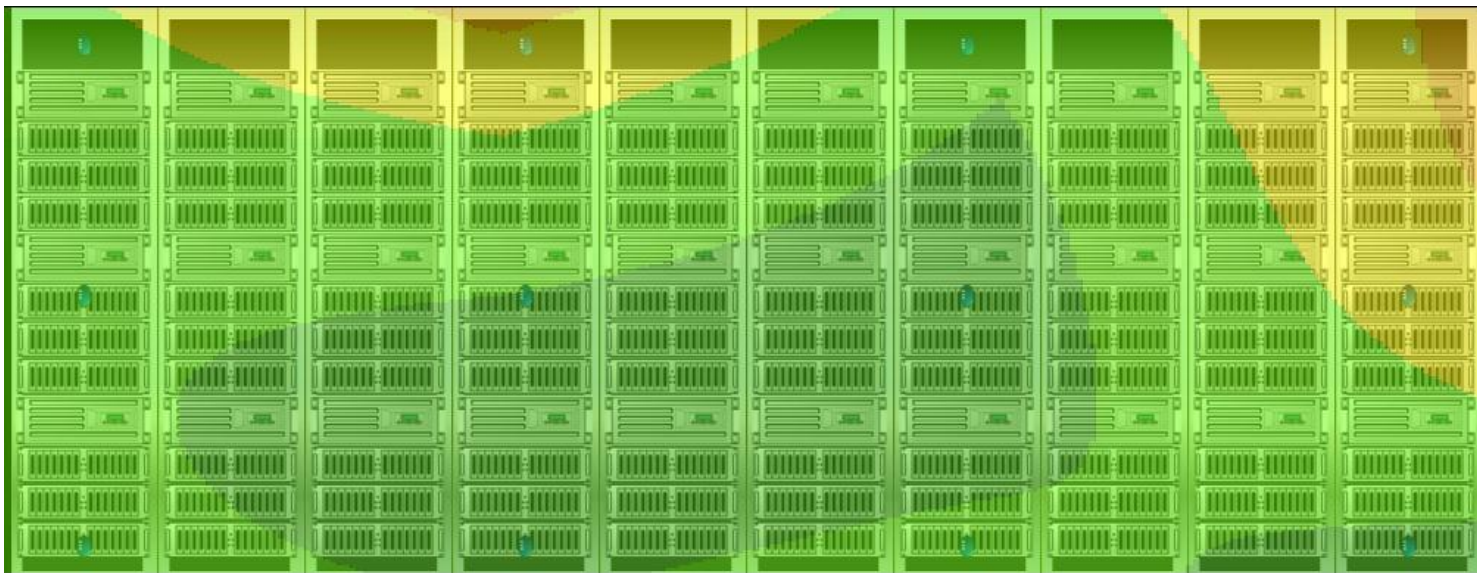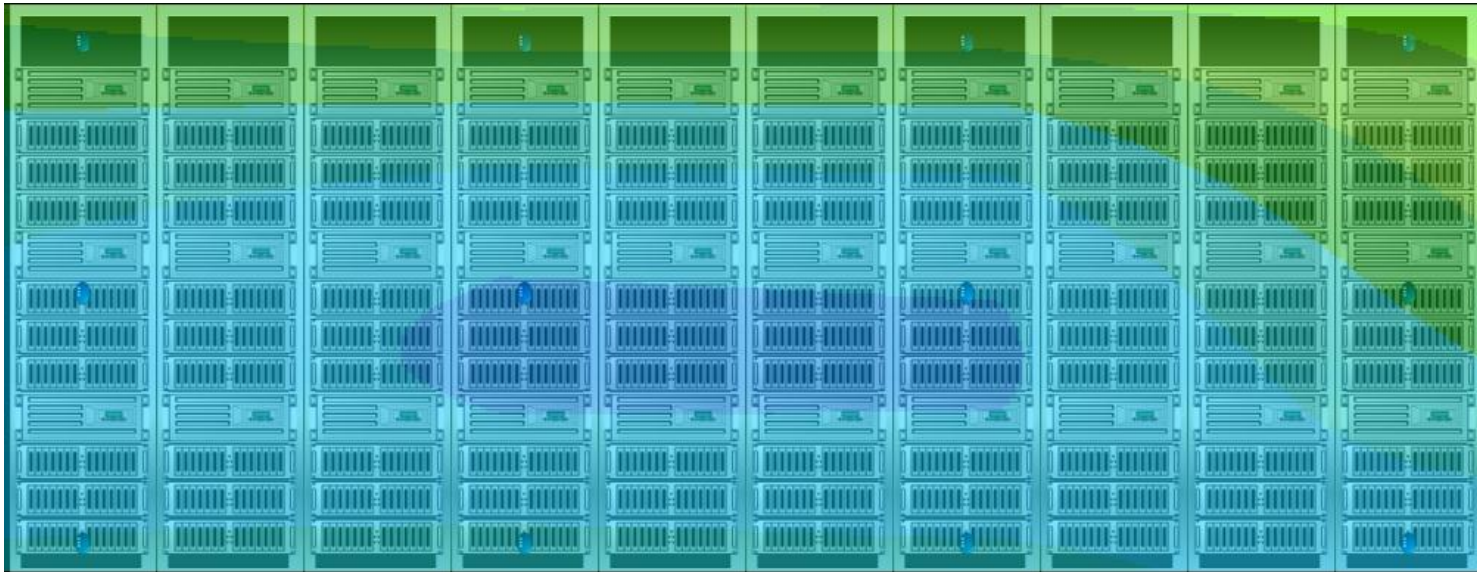energy goes into Air-conditioning

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

VM Migration can be used for
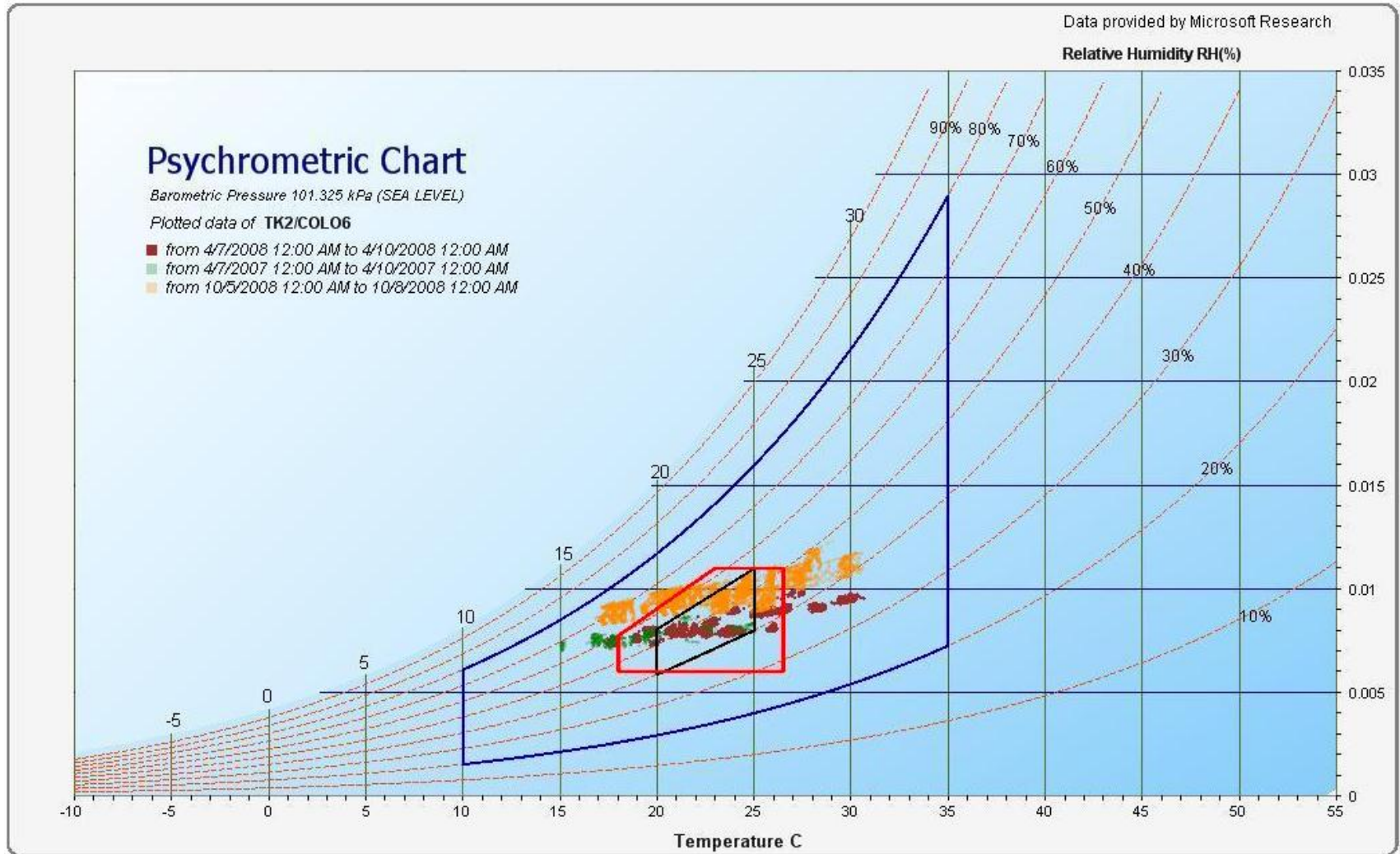power capping reasons (NSDI 2008)

Step 1: Data Visualization

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Temperature Contour Maps

Psychrometric charts

Conclusion

Things we learnt

- Smart software design helps but must weigh complexity against gains

  ◆ IT adopts technology if it saves them <u>significant</u> 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 helps change habits and is necessary for improving architecture & design

The really green things:

- Tele conferencing / video immersion, get it right and win big!