

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](#))

Home & Office Computing

Battery Powered Computers



Lenovo X61 laptop

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

“Wall Powered” Computers



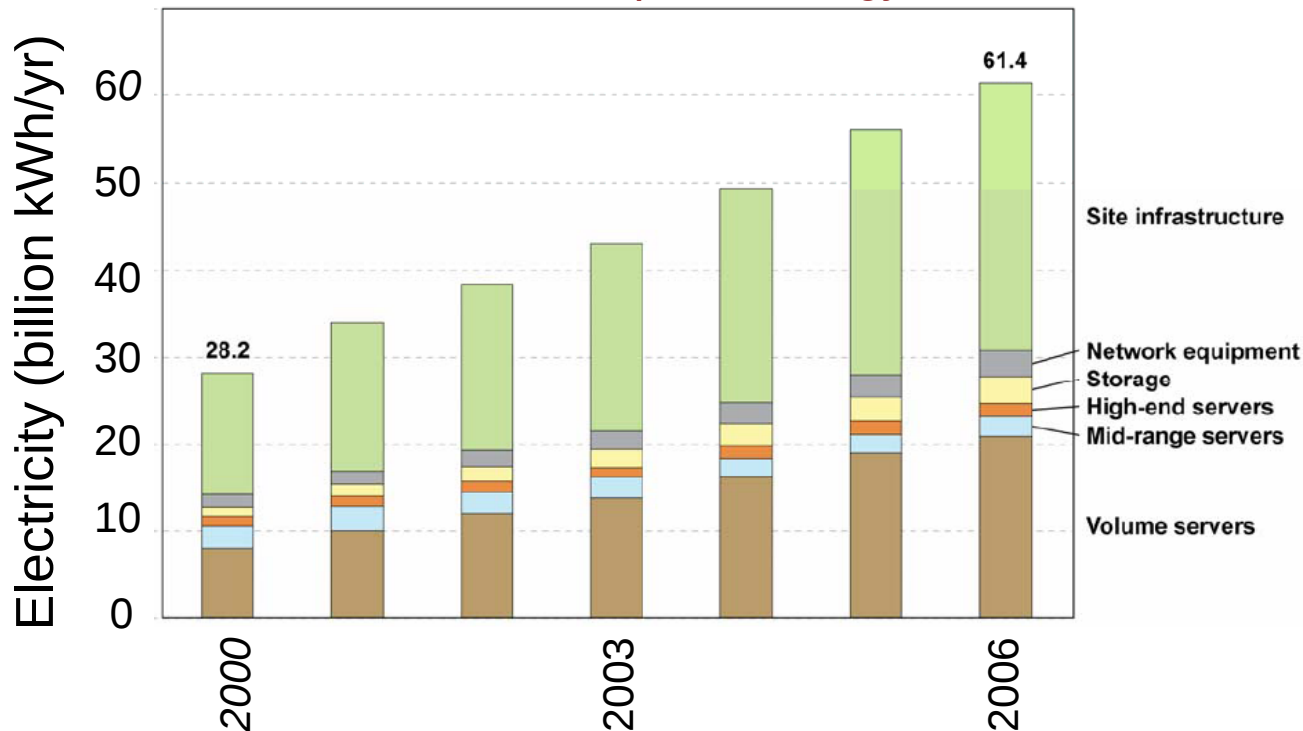
Dell Optiplex 745 desktop

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 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

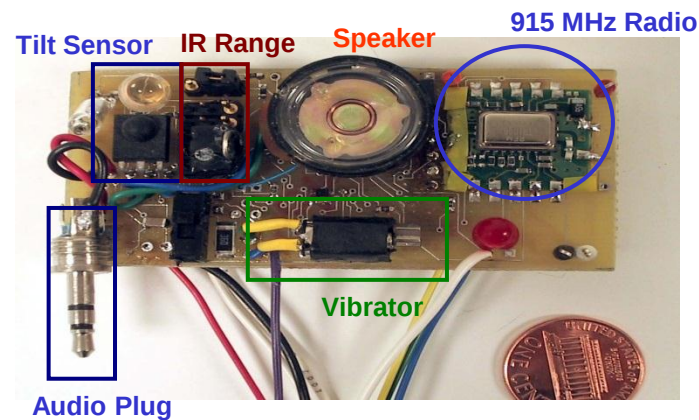
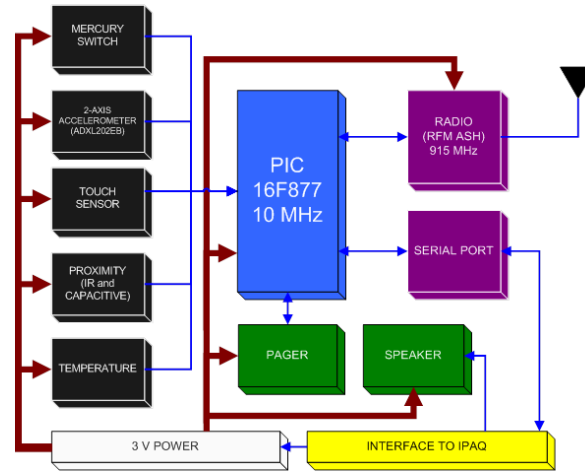
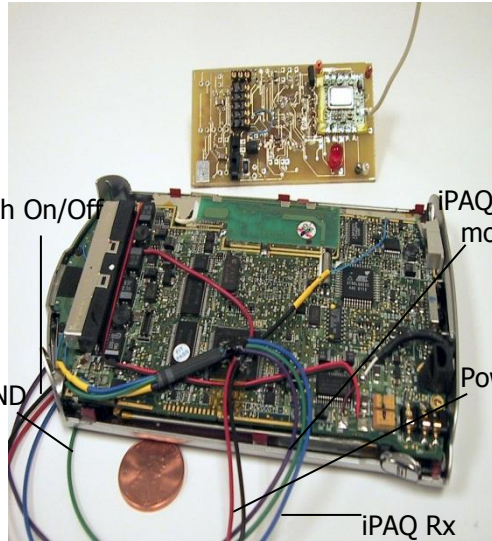
Datacenter energy (excluding small DC's, office IT equip.) **equals** electricity used by the entire U.S transportation manufacturing industry (manufacture of automobiles, aircraft, trucks, and ships)

In the beginning....

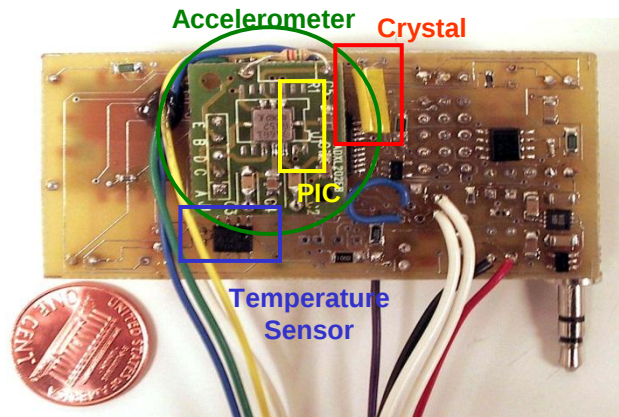
SmartPhone Energy Management

Wake on Wireless (2001-02)

LPR to a Trigger Wakeups



Front View

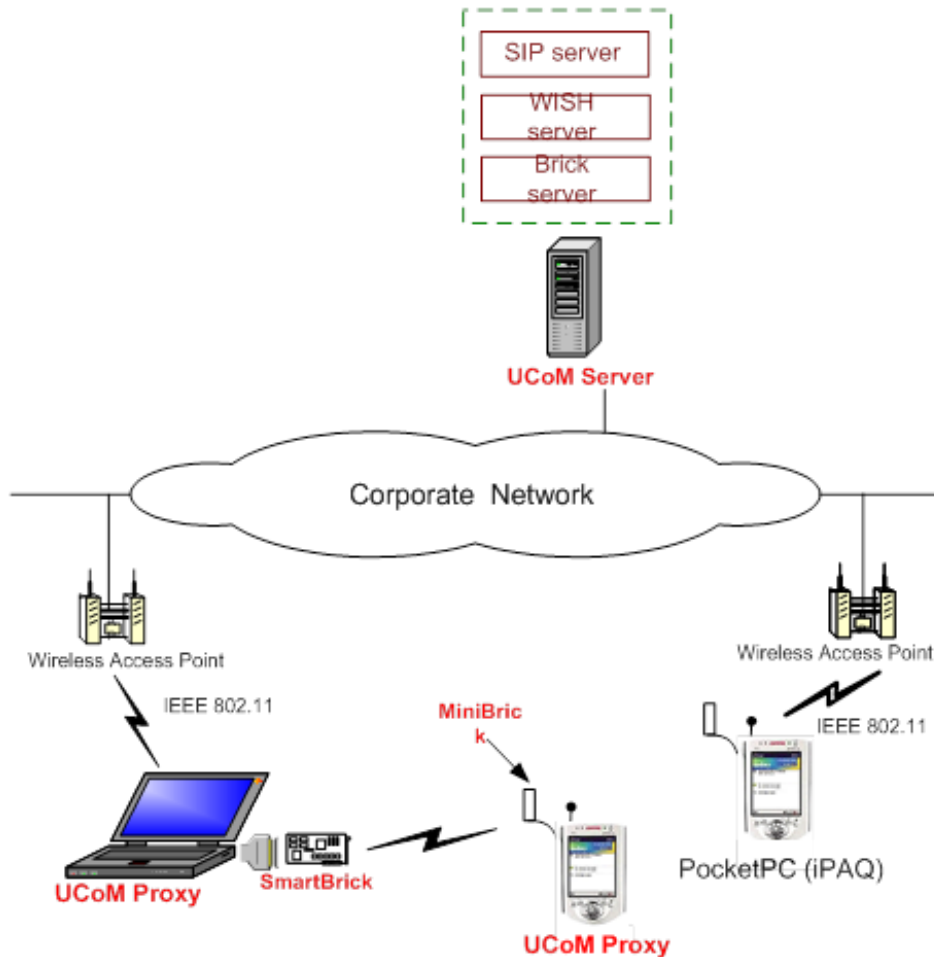


Back View

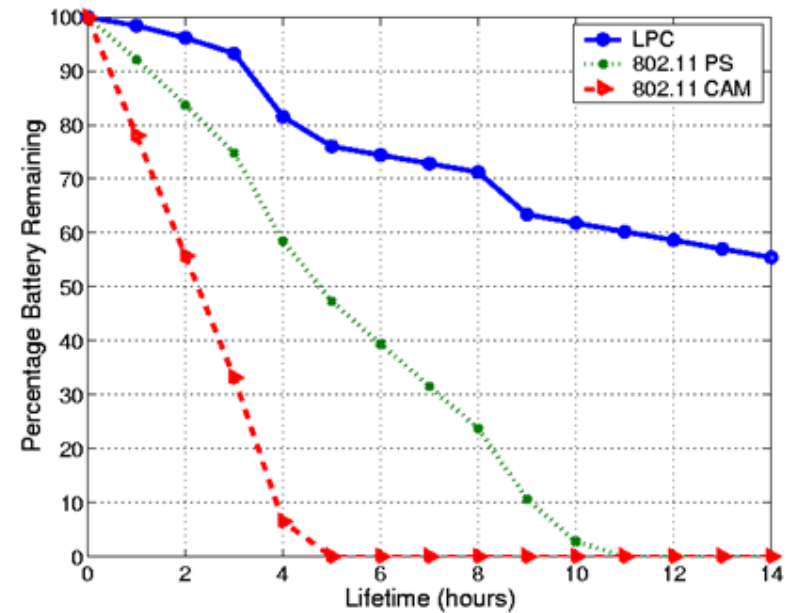


Wake on Wireless with LPR

Energy Saving



2001-02

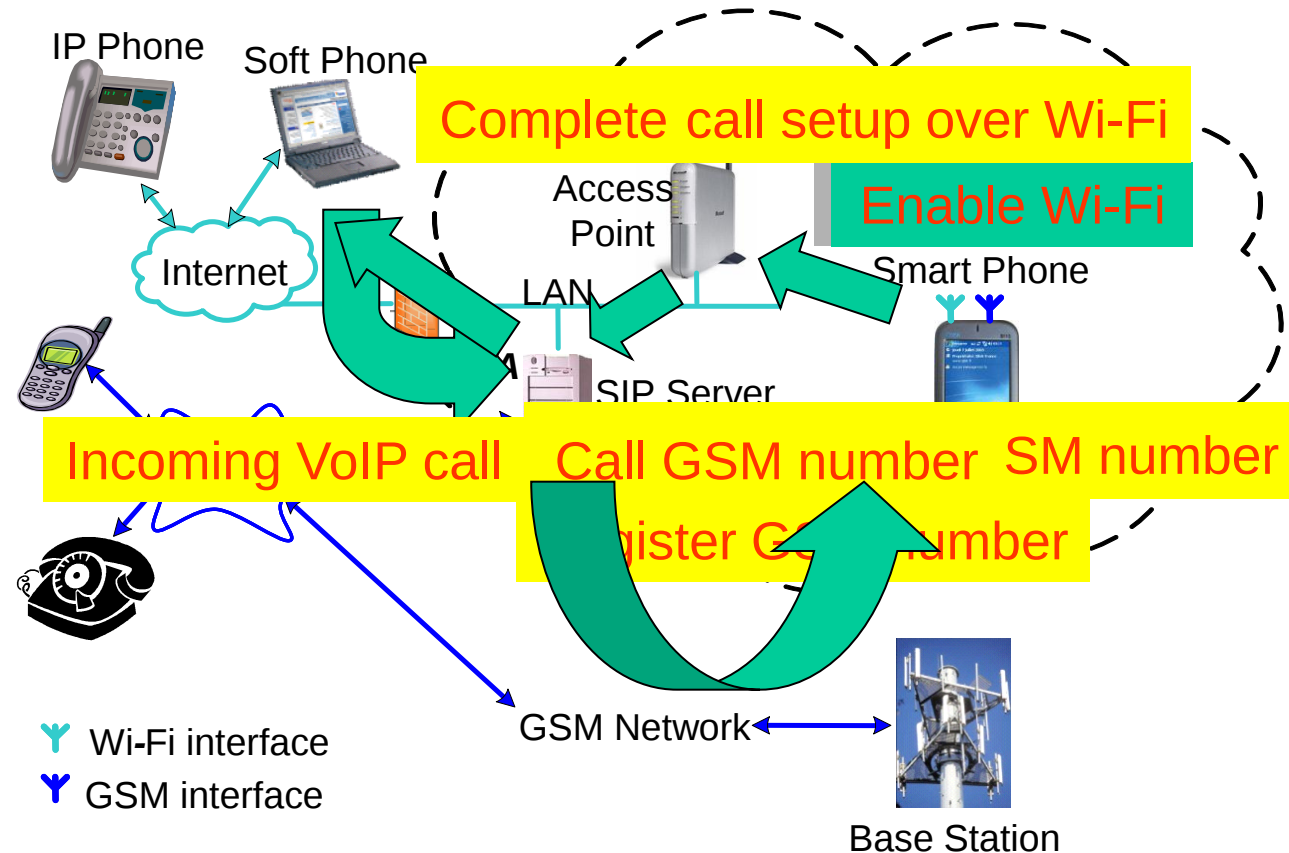


Wake on Wireless (2005-07)

MobiSys 2007

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

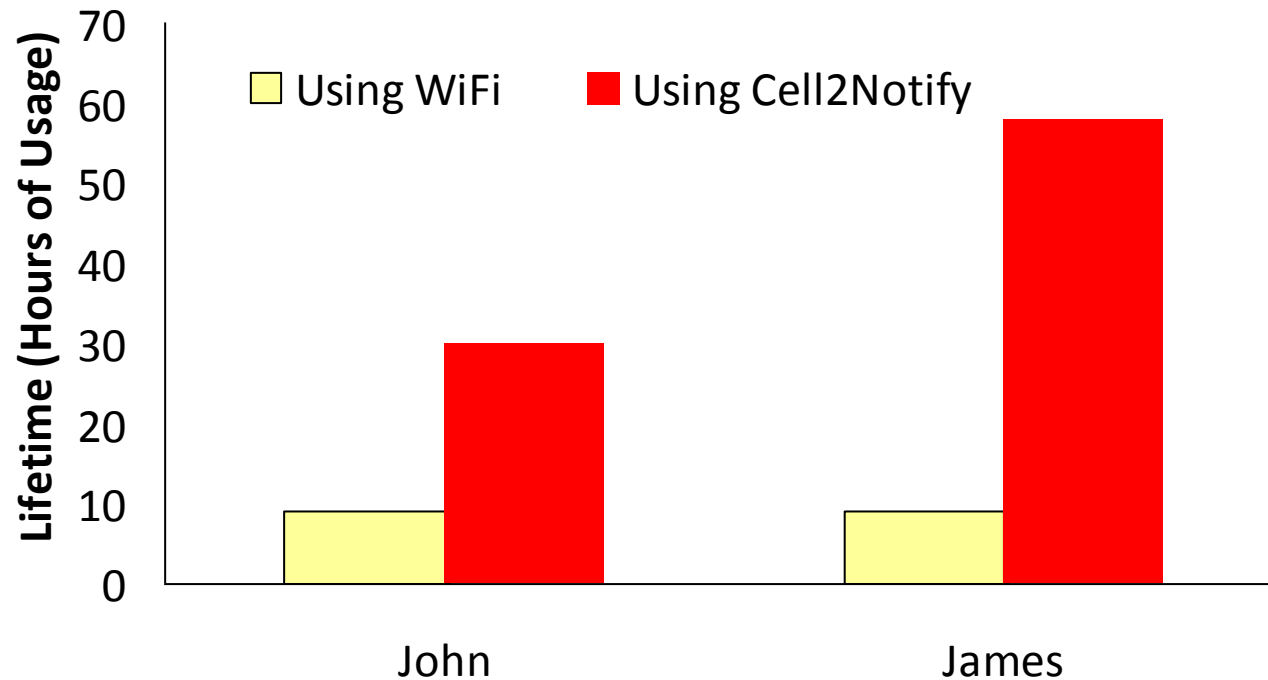
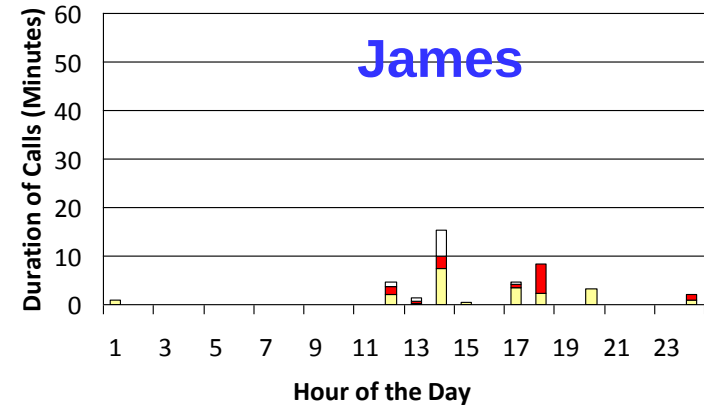
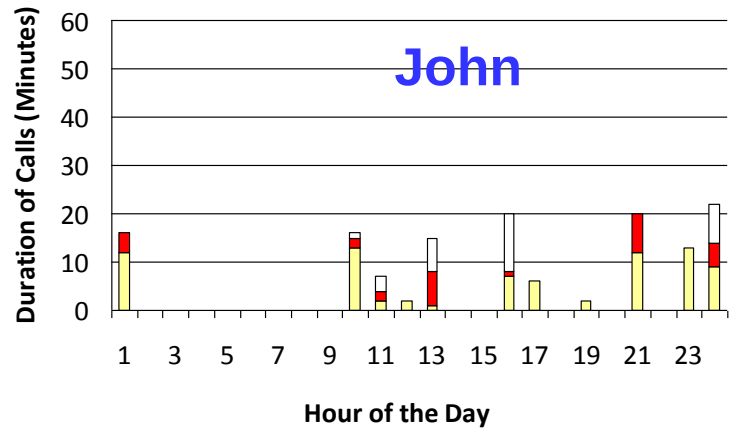


Security: SIP Server uses different caller ID every time

Wake on Wireless with Cell2Notify

MobiSys 2007

Energy Savings



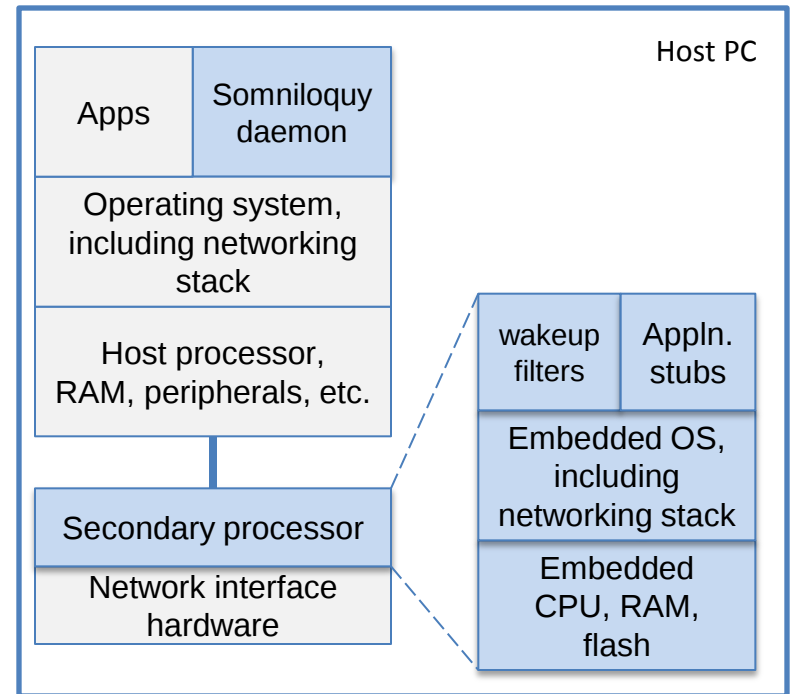
***... extending the concept of sleeping to home
& enterprise***

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”

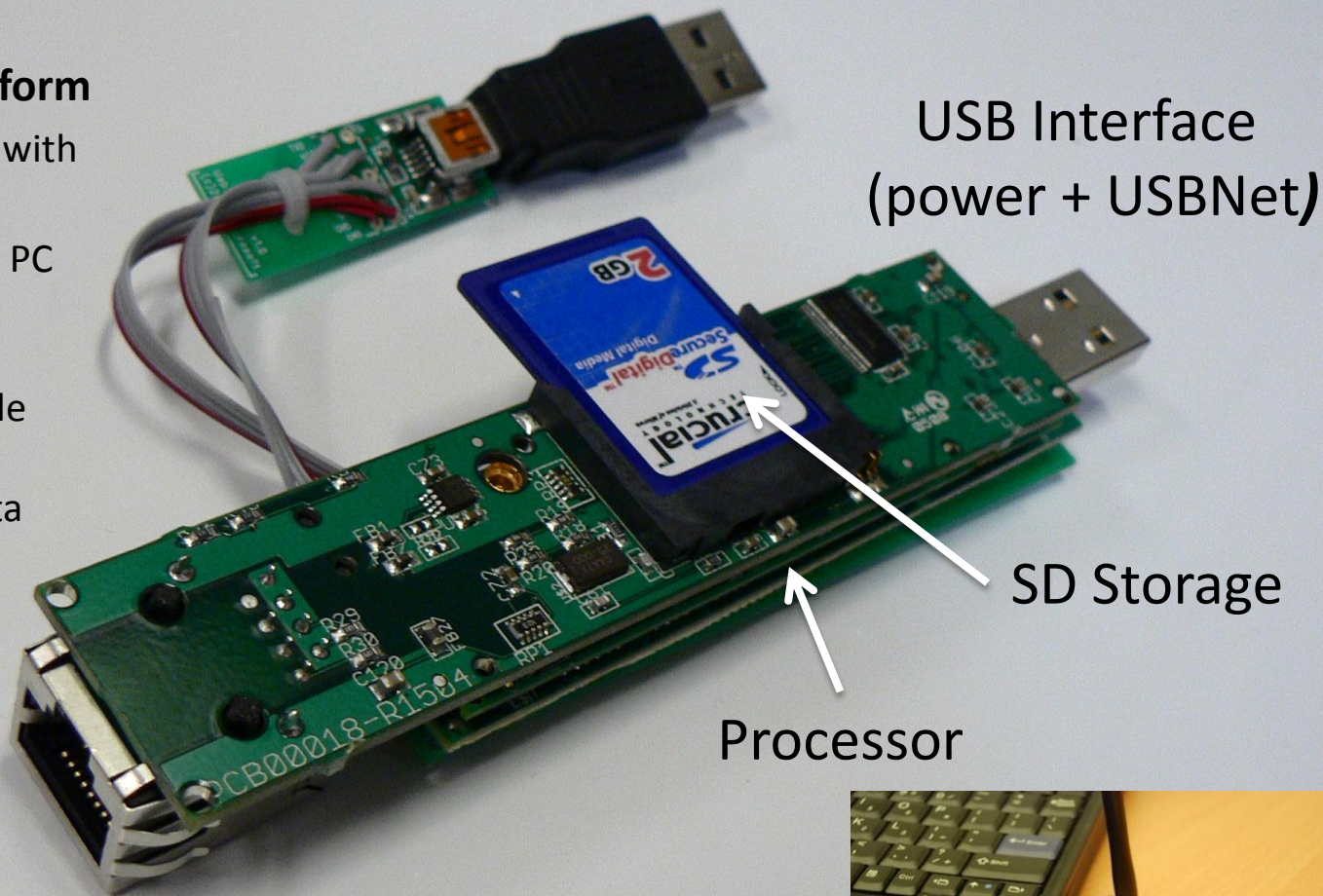


Somniloquy

USB Interface
(Wake up Host + Status + Debug)

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



100Mbps Ethernet Interface



Somniloquy

Power Savings

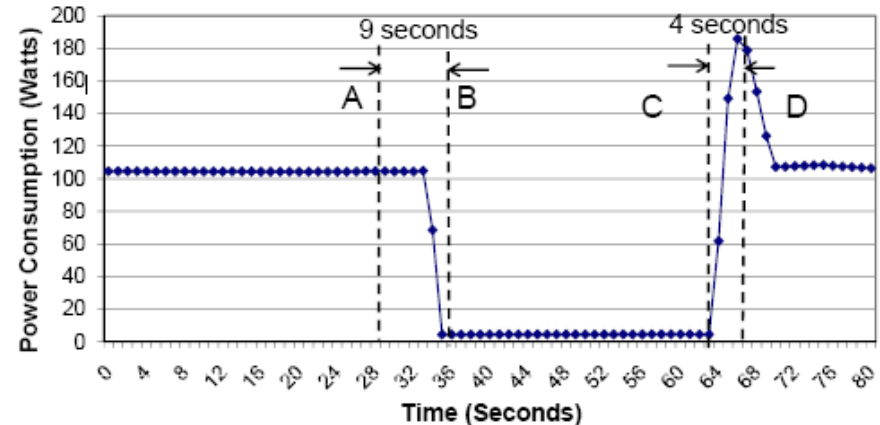
State	Power
Normal Idle State	102.1W
Lowest CPU frequency	97.4W
Disable Multiple cores	93.1W
"Base Power"	93.1W
Suspend state (S3)	1.2W

For Desktops

- Power drops from >100W to <5W
- Assuming a 45 hour work week
 - **620kWh saved per year**
 - **US \$56 savings, 378 kg CO₂**

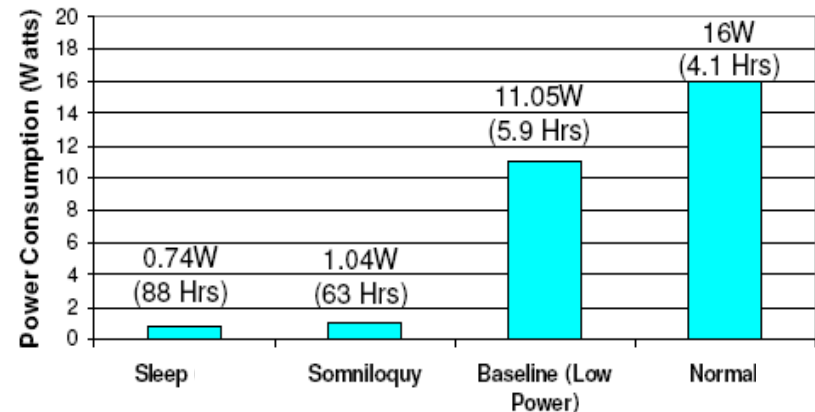
For Laptops

- 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



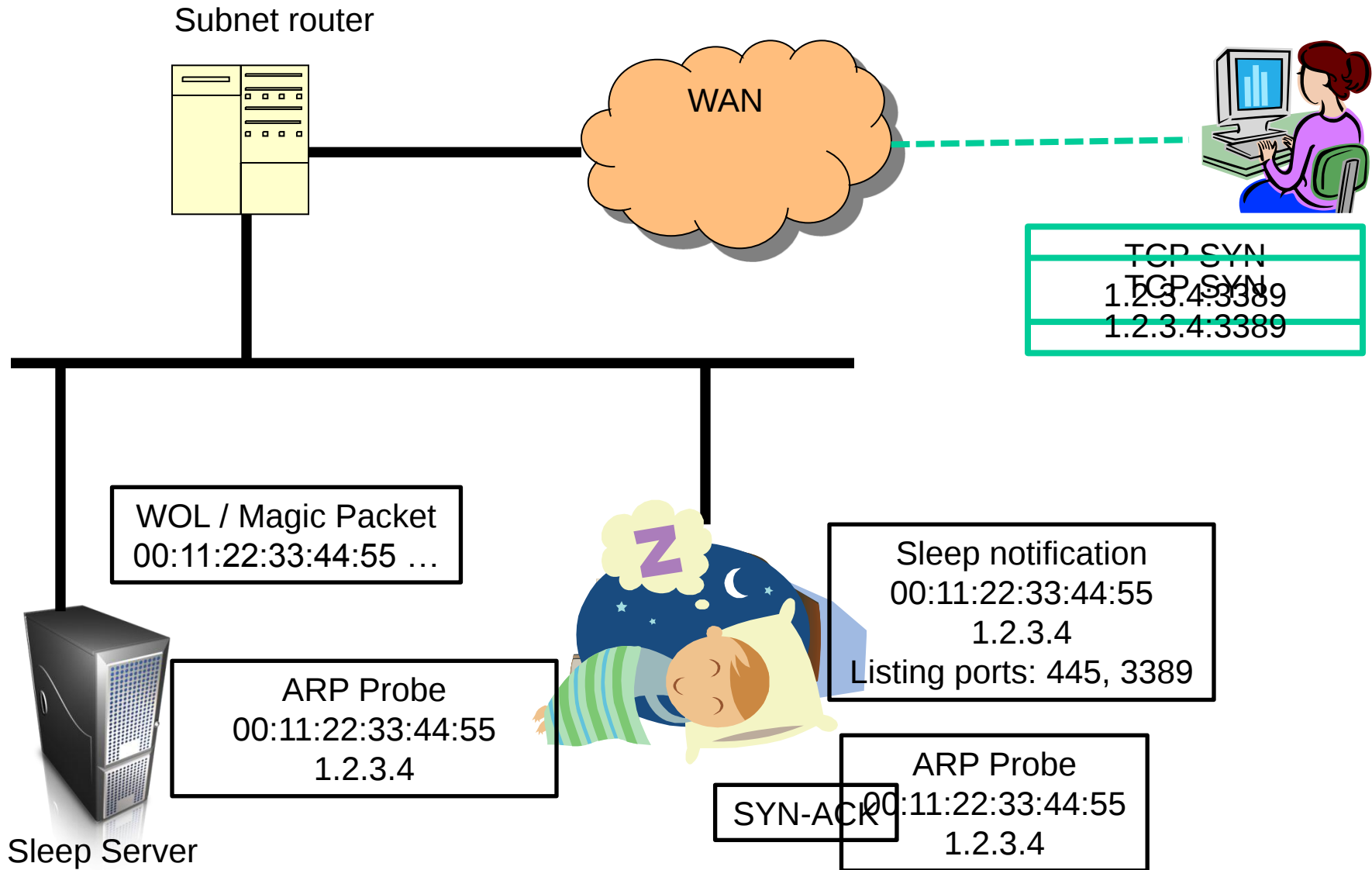
Dell Optiplex 745 Power Consumption and transitions between states

IBM X60 Power Consumption

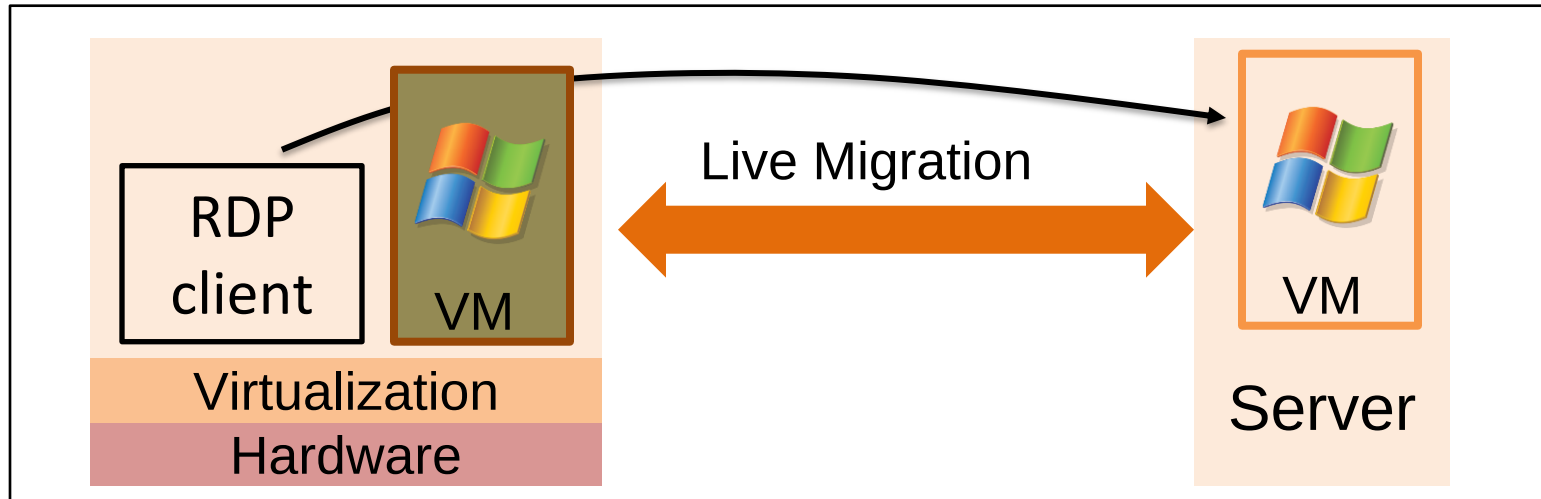


SleepProxy: A Software-only Enterprise Solution

USENIX ATC 2010



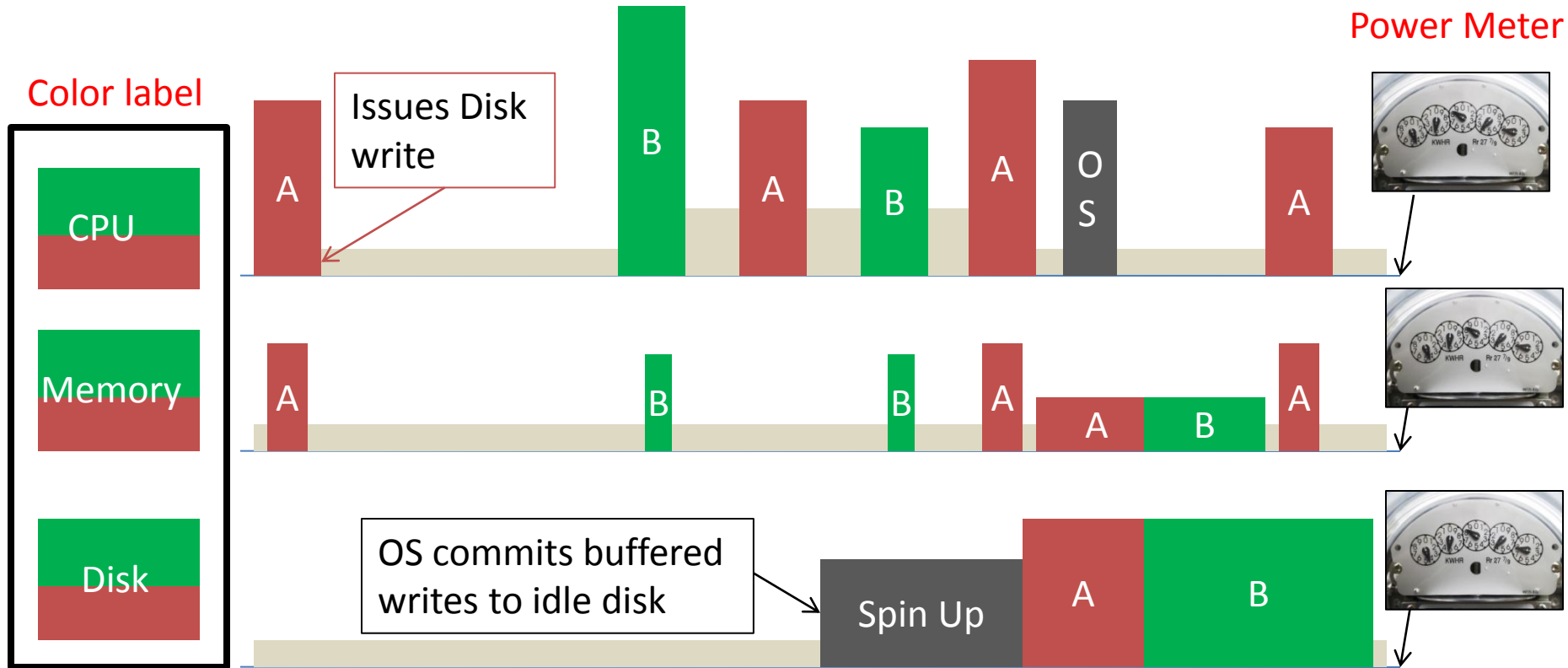
LiteGreen: A VM Based Solution



- 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

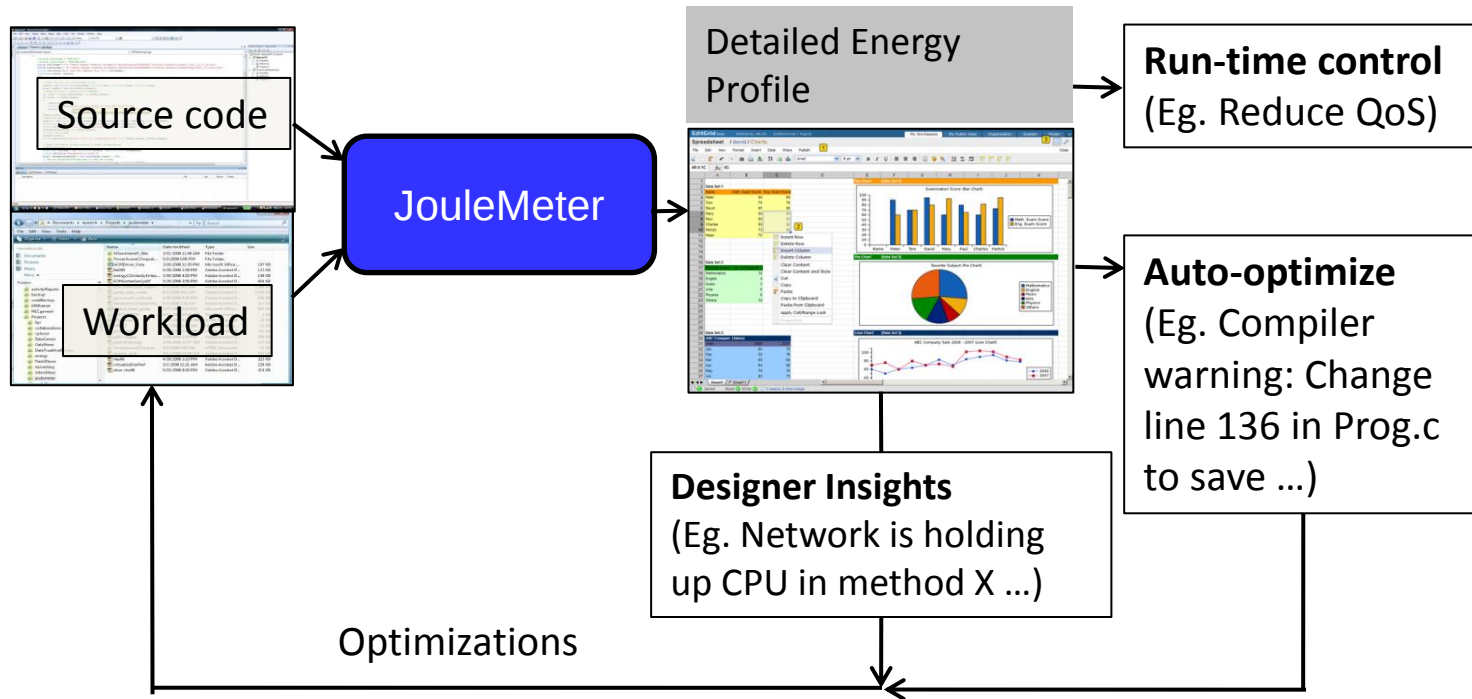
Application Energy Measurement Using Performance Events



- $\text{Energy}(\text{App A}) = \Sigma (\text{red rectangles})$
 - Other components: Network, GPU, ... (Not in current version)

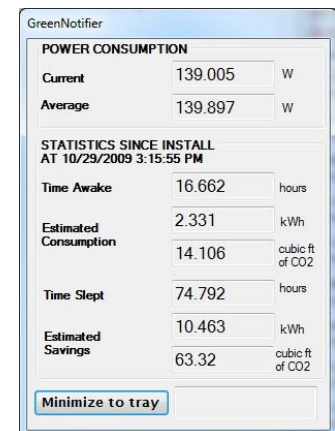
Fine Grained Visibility

Measure application energy usage in depth



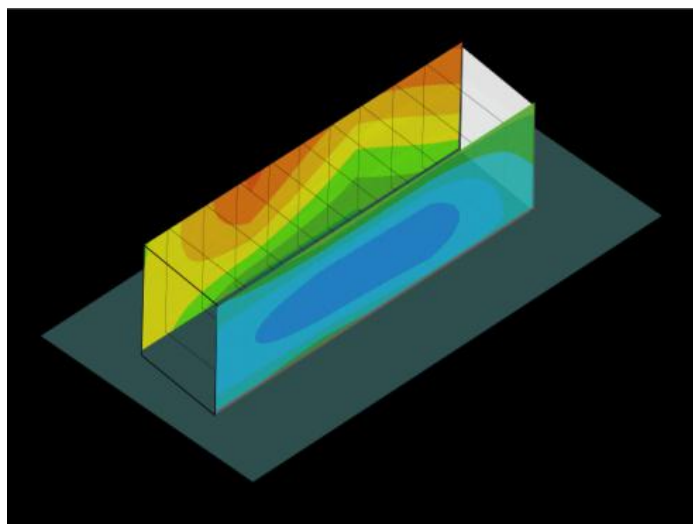
GreenClient: Provides energy usage stats to user

- Current power draw
- Historical savings



...About transparency, take on the big beast

Datacenter Energy Management

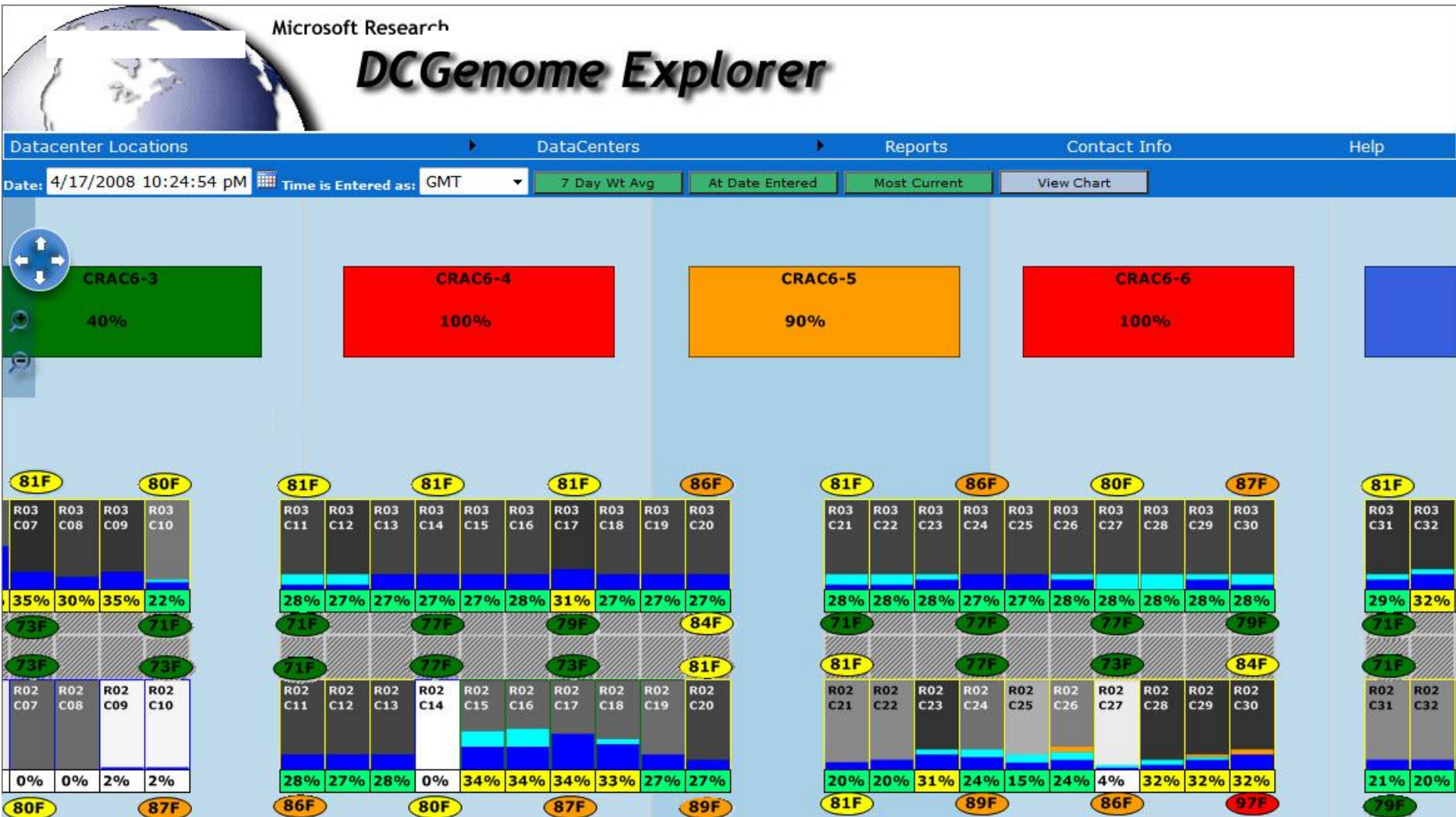


In poorly designed DC, 50% of the energy goes into Air-conditioning

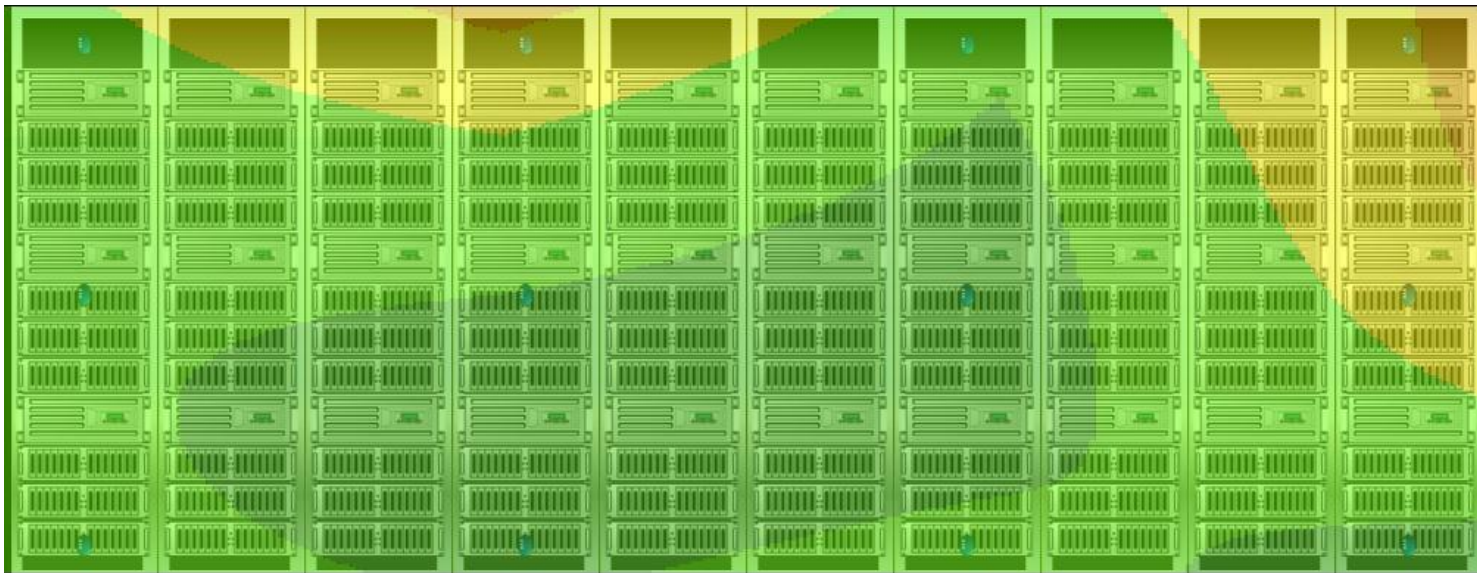
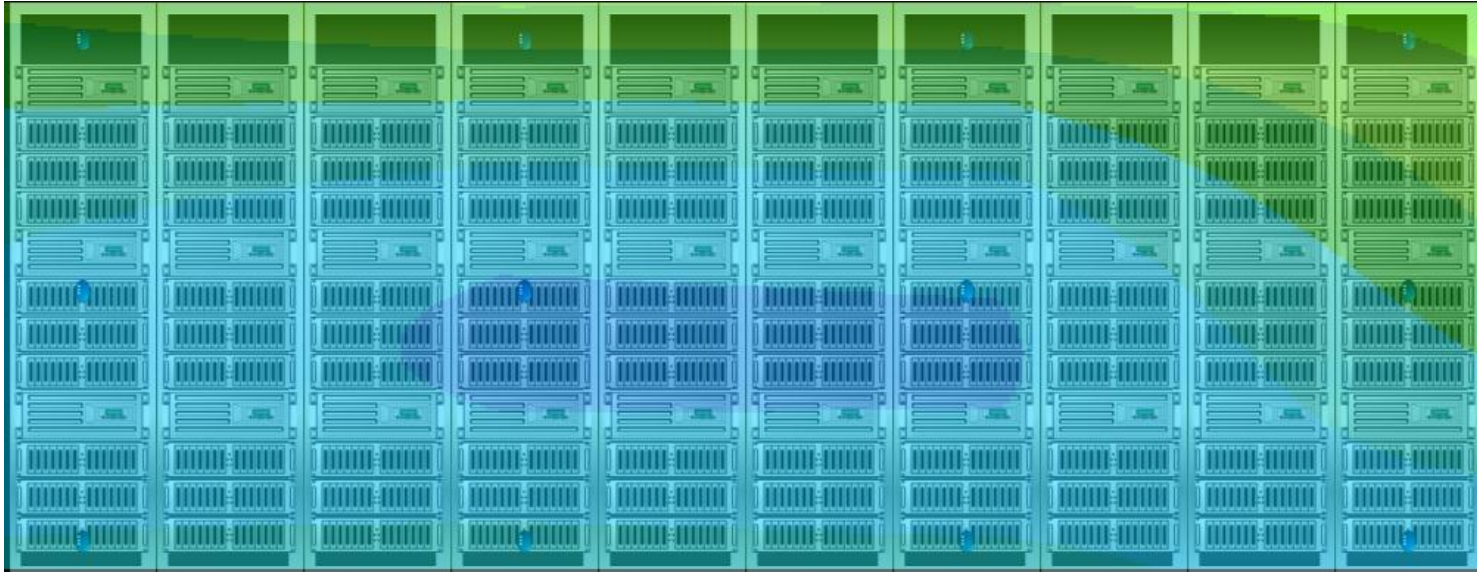
30% of the servers can be turned for Messenger traffics (NSDI 2008)

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

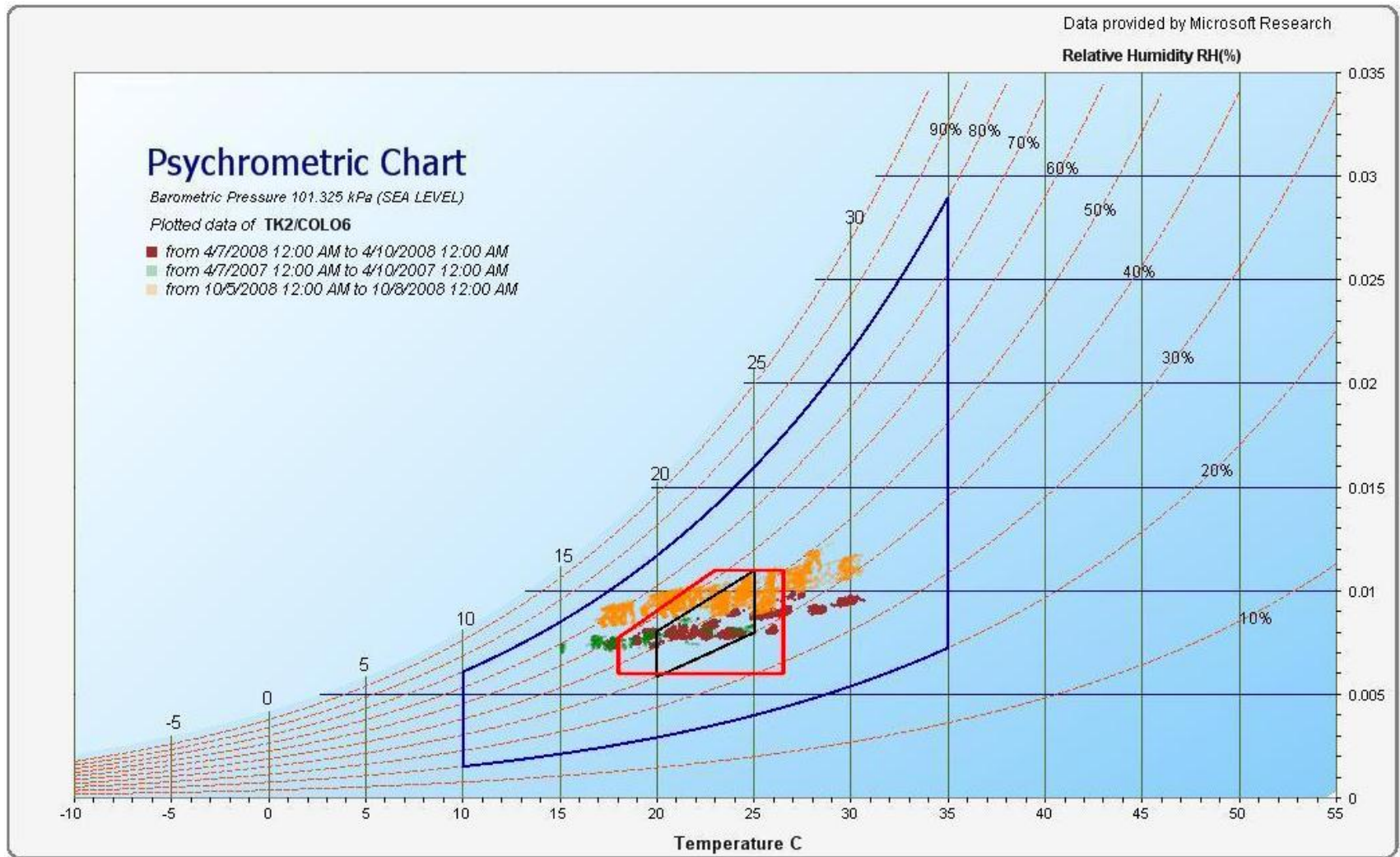
Step 1: Data Visualization



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 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 helps change habits and is necessary for improving architecture & design

The really green things:

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