EEDN Seminar

Proxying: Reducing PC Energy Use With Network Technology

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September 10, 2010

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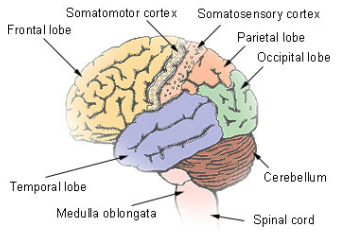
What is a Proxy?

"An entity that acts on behalf of another"
e.g. attorney, ambassador

Brain analogy

- When asleep, small portion maintains critical functions and monitors external stimulus; enables great majority of brain to go offline



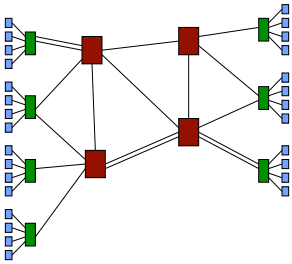
Lobes of the cerebrum

Source: Wikipedia

What is a Network?

Mechanism for arbitrary communication among devices

- Enables functions not otherwise possible
- Requires infrastructure
  - Data links
  - Network equipment
  - Protocols



Source: Nordman, Invited talk: UC Berkeley CITRIS I4E Research Seminar Series

Hypotheses

- Proxying can address a key barrier to reducing PC energy use
- Proxying can be specified
- Proxying can be brought into products

Agenda

- Electronics energy use
- PC energy use
- How proxying works
- Proxy development
- Trace analysis
- Today and future

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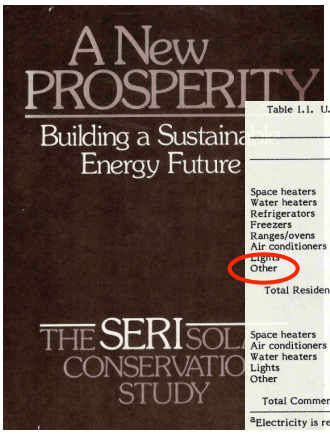
Origins



Electronics lost in "other" energy use

1977

Table 1.1. U.S. BUILDINGS ENERGY USE BY SECTOR, FUEL, & END USE - 1977 (10^{15} Btu)

	Electricity[a]	Gas	Oil	Other	Total
Residential					
Space heaters	1.25	3.64	2.26	0.54	7.69
Water heaters	1.17	0.87	0.14	0.08	2.25
Refrigerators	1.49				1.49
Freezers	0.64				0.64
Ranges/ovens	0.52	0.31			0.83
Air conditioners	1.10				1.10
Lights		0.96			0.96
Other	0.68	0.48			1.15
Total Residential	7.81	5.30	2.40	0.62	16.12
Commercial					
Space heaters	0.37	1.94	1.90	0.35	4.56
Air conditioners	2.03	0.16			2.19
Water heaters	0.04	0.09	0.10		0.23
Lights	2.23				2.23
Other	0.85	0.20			1.05
Total Commercial	5.62	2.39	2.00	0.35	10.36

[a]Electricity is reported as primary energy (11,500 Btu/kwhr).

Electronics are an end use of energy

2008

- Now at least 290 TWh/year in U.S.
  - 11% of buildings electricity, and rising
- Majority already networked, and increasing
- < 20% occurs in data centers

Electronics are:

"Devices whose primary function is information"

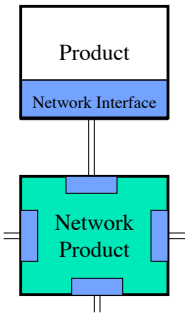
–Computation, communication, storage, display

Nordman, Bruce, and Marla Sanchez 2006. "Electronics Come of Age: A Taxonomy for Miscellaneous and Low Power Products." Proceedings: 2006 ACEEE Summer Study on Energy Efficiency in Buildings.

Networks drive energy use two ways

- **Direct**
  - –Network interfaces (NICs)
  - –Network equipment
- **Induced** in Networked products
  - –Increased power levels
  - –Increased time in higher power modes (to maintain network presence)

Network induced consumption **>** **all** direct



Network equipment ….
Routers, switches, modems, wireless APs, …

… vs **networked** equipment
PCs, printers, set-top boxes, …

Network change the rules

- The behavior on the network of one device can change the energy use of devices it is connected to
- For information technology, technology standards serve the role the laws of physics play for other end uses
  - Can prohibit *or* require energy-saving features

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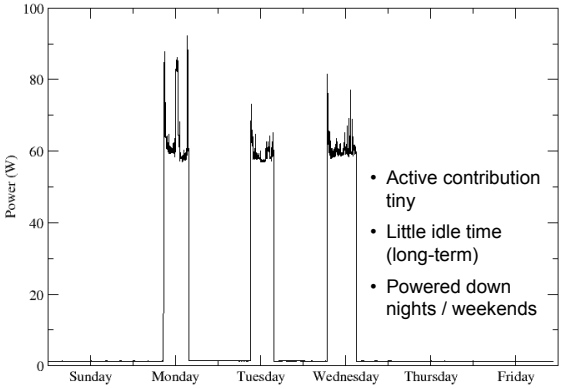
- Electronics energy use
- PC energy use
- How proxying works
- Proxy development
- Trace analysis
- Today and future

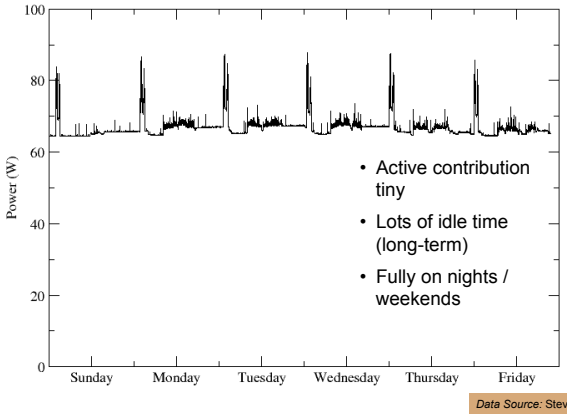
ENERGY EFFICIENT DIGITAL NETWORKS

PC energy use: Desktop PC "A"
B90, August 2010



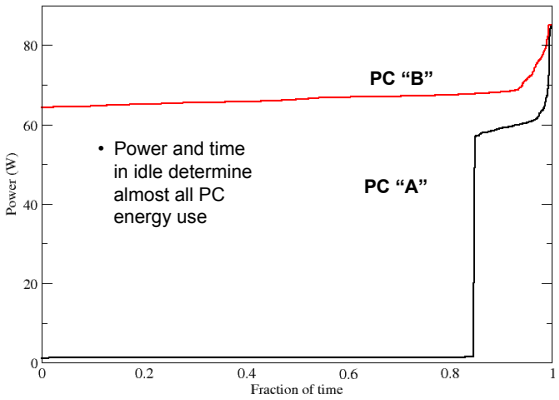
Data Source: Steven Lanzisera

PC energy use: Desktop PC "B"
B90, August 2010

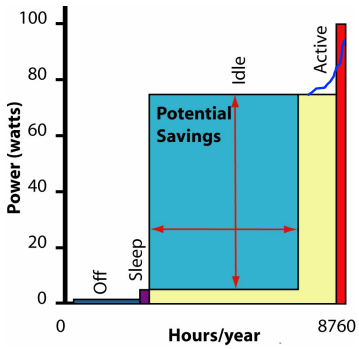


Data Source: Steven Lanzisera

PC energy use: Desktop PCs "A" and "B"
Load Duration Curves



Most PC energy use occurs when no one present



Graph shows all time for year sorted by power level for average desktop PC – most are fully on most of time

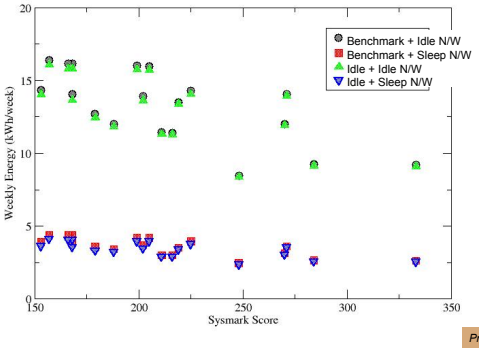
Sleep/off power similar

Idle time driven by nights and weekends

All PCs in U.S. about 80 TWh/year - **$8 billion**/year (adding monitors – 100 TWh/ year - **$10 billion**/year)

PC energy use: Benchmark-based estimates

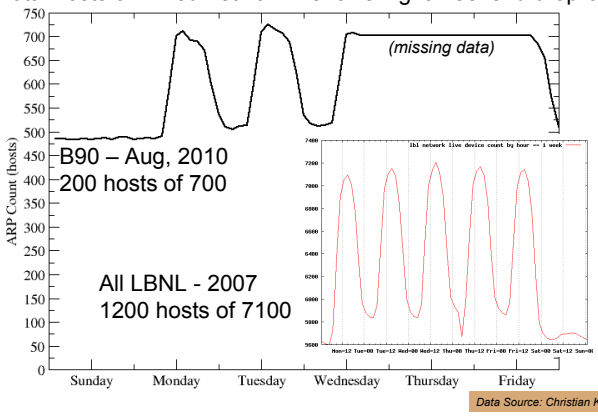
Weekly energy — active energy: with and without;
— nights/weekend status: asleep and awake



Prepared for Ecma TC32-TG21

LBNL network night staus

Total hosts on wired network – shows night/weekend drop-off



Data Source: Christian Kohler

Why are PCs on when no one is present?

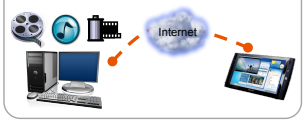
People lack(ed) good alternatives

- "**Off**" is problematic
  - Slow to reboot; lose application state
- **Sleep** had four big problems in 1995

– Confusing user interface	Addressed by IEEE 1621
– Poor reliability of hardware and software	Industry has essentially solved
– Long latency to being usable	New Windows machines wake in < 2 seconds
– Lose network connectivity	**Subject of this talk**

Always-Connected PC Uses

Remote Media Access
Access personal photos, music, or movies on your home PC from outside the home



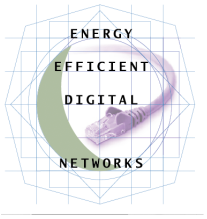
Internet Telecommunications
Receive VoIP & video calls at any time

Resource Sharing
Share printers or storage devices in the home

Maintenance Services
Allow an IT service provider to upgrade and maintain your PC remotely

Source: **Intel**

Agenda



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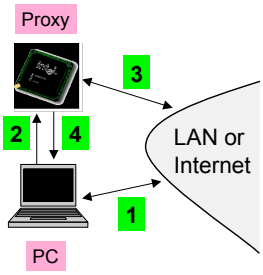
Proxying goals

- Enable "full" network connectivity in sleep
  - Hide fact of being asleep from rest of network
  - Method: Transfer "network presence" from PC to proxy on going to sleep (return on wake)

- What about Wake-on-LAN (WoL) ?
  - Requires rest of network to understand sleep status and act differently because of it
  - Generally leads to waking up too often or not often enough
  - Has not been successful since introduction in 1994
- *Another alternative:* Change applications and protocols to understand sleep states and change behavior

Proxy operation

1. **PC awake; becomes idle**
2. **PC transfers network "presence" to proxy on going to sleep**
3. **Proxy responds to routine network traffic for sleeping PC**
4. **Proxy wakes up PC as needed; returns presence to PC**

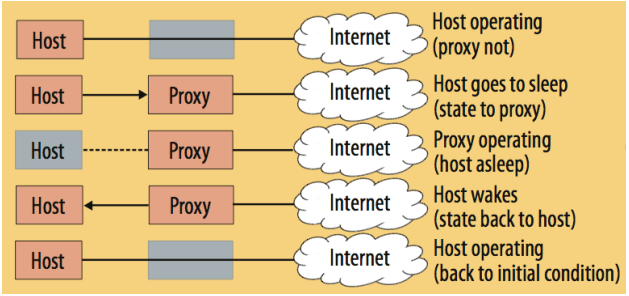


Proxy can be internal (NIC), or external (elsewhere on network)

Proxy handles Internet Protocol traffic

Source: *IEEE 802.3 Plenary*, Nordman and Christensen, 2005

Proxy operation



Source: *IEEE Network*, Nordman and Christensen, 2010

The proxying solution

- Should be simple, transparent for user
- Should not require changes to other hardware, other software
- Require only modest changes in PC hardware, software
- Apply to any "PC-like" device
  - PCs, printers, set-top boxes, game consoles, servers …

  –Need for persistent network connectivity

  –Non-trivial difference between idle/sleep power

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History

- ARPA-net begins operation
- Ethernet invented

1969

1973

1979

HP Labs

History, cont.

- Dawn of PC era

1980

- First commercial Ethernet switch

1990

- First paper on all IT energy use

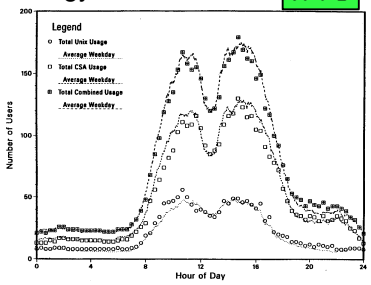
1990

ANNUAL REVIEW OF ENERGY

VOLUME 15, 1990

ELECTRICITY USE IN INFORMATION TECHNOLOGIES

Loadshape of IT remote usage based on data from IT equipment



History, cont.

- Launch of ENERGY STAR program

1992

  - Began with PCs and monitors
  - Specified sleep power levels
  - Required a specific technology — DPMS
    (Display Power Management Signaling)
    - DPMS is a data interface standard

ENERGY STAR

- LBNL initiates PC power management research

1995

  - Addressed from beginning problems networks introduce

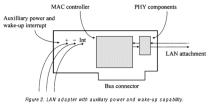
Nordman, Bruce, Mary Ann Piette, Kris Kinney, and Carrie Webber 1997. *User Guide to Power Management for PCs and Monitors*. LBNL-39466.

Nordman, Bruce, Alan Meier, and Mary Ann Piette 2000. *"PC and Monitor Night Status: Power Management Enabling and Manual Turn-Off"*. Proceedings: ACEEE 2000 Summer Study on Energy Efficiency in Buildings.

Piette, Mary Ann, Bruce Nordman, Kris Kinney 1996. *"Measured Energy Savings and Performance of Power-Managed Personal Computers and Monitors."* Proceedings: 1996 ACEEE Summer Study on Energy Efficiency in Buildings, LBL-38057.

History, cont.

Network Proxying first appears in literature



INTERNATIONAL JOURNAL OF NETWORK MANAGEMENT
Int. J. Network Mgmt., 8, 120–130 (1998)

1998

Enabling Power Management for Network-attached Computers

Power management is an emerging area of interest for network management. This article reviews current developments and describes methods for enabling power management in network-attached computers. © 1998 John Wiley & Sons, Ltd.

By Kenneth J. Christensen and Franklin 'Bo' Gulledge*

Acknowledgments

Thanks are due to Bruce Nordman and Jeff Harris, both from the Lawrence Berkeley National Laboratory, for their helpful and insightful comments during the course of this project.

History, cont.

- Initiated work on Power Control User Interface Standard

2000

  - Eventually IEEE 1621

IEEE Microprocessor Standards Committee of the IEEE Computer Society. "*P1621, Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments*." (approved December, 2004; reaffirmed December, 2009).

Nordman, Bruce 2003. *The Power Control User Interface Standard — Final Report*. prepared for the California Energy Commission, Public Interest Energy Research Program, LBNL-52526.

  - Users as 'nodes on the network'

- Began collaborating with Prof. Ken Christensen

2002

  - Considered many aspects of energy and networks

Christensen, Ken, Chamara Gunaratne, Bruce Nordman, and Alan George 2004. "*The Next Frontier for Communications Networks: Power Management*." Computer Communications, Vol. 27, No. 18, pp. 1758-1770, December 2004.

Christensen, Ken, Bruce Nordman, and Rich Brown 2004. "Power management in networked devices." IEEE Computer, LBNL-55816, August, 2004.

  - External proxy shown to work

History, cont.

2003

- Continued collaboration with Ken Christensen
  - Developed internal proxy concept

Gunaratne, Chamara, Ken Christensen, and Bruce Nordman 2005. *"Managing Energy Consumption Costs in Desktop PCs and LAN Switches with Proxying, Split TCP connections, and Scaling of Link Speed."* International Journal of Network Management. 2005.

M. Jimeno, K. Christensen, and B. Nordman 2008. *"A Network Connection Proxy to Enable Hosts to Sleep and Save Energy."* Proceedings: IEEE International Performance Computing and Communications Conference, pp. 101-110, December 2008.

M. Allman , K. Christensen, B. Nordman, and V. Paxson 2007. *"Enabling an Energy-Efficient Future Internet Through Selectively Connected End Systems"*. Proceedings: Sixth Workshop on Hot Topics in Networks (HotNets-VI), November 2007.

J. Klamra, M. Olsson, K. Christensen, and B. Nordman 2005. *"Design and Implementation of a Power Management Proxy for Universal Plug and Play."* Proceedings: Swedish National Computer Networking Workshop (SNCW 2005) in September 2005.

  - "Energy Efficient Ethernet" a by-product

IEEE 802 Energy Efficient Ethernet

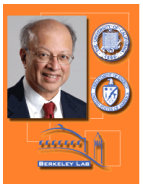
IEEE LAN/MAN Standards Committee of the IEEE Computer Society. "Draft P802.3azTM/D3.0, Draft Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements. Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control parameters, Physical Layers and management parameters for Energy-Efficient Ethernet." (September, 2010)

Proxies have technology requirements

- Device must maintain link
  - Already done for Ethernet/WoL (not for WiFi)
- Proxy must have
  - Processor (memory, codespace, etc.)
  - Power - system asleep
  - Ability to wake PC
  - Responsibilities (software)
    - Protocols and behaviors
    - Configuration

EETD's mission statement

environmental energy technologies division

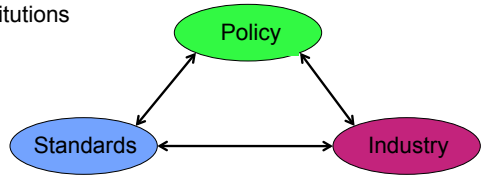


The mission of Berkeley Lab's Environmental Energy Technologies Division is to perform analysis, research and development leading to better energy technologies and reduction of adverse energy-related environmental impacts. Our work increases the efficiency of energy use, reduces its environmental effects, provides the nation with environmental benefits, and helps developing nations achieve similar goals through technical advice.

Two paths to get proxying into future PCs

- Option A: Create technology by ourselves
  - Unlikely to be successful in market
- Option B: "Encourage" industry to create technology
  - Industry takes ownership

Hypothesis: Success requires careful choreography of 3 institutions



Nordman, Bruce and Ken Christensen 2007. *Improving the Energy Efficiency of Ethernet-Connected Devices: A Proposal for Proxying.* White Paper, Version 1.0, prepared for Ethernet Alliance.

Energy Star promotes proxying

2004

- Put "Network Problem" on EPA's priority list to industry

2006

- PC spec V 4.0 (effective 2007)
  - Proxying not included

2008

- PC spec V 5.0 (effective 2009)
  - PCs with proxying much easier to qualify
  - Required industry standard to get proxy credit

Full Network Connectivity: **The ability of the computer to maintain network presence while in sleep and intelligently wake when further processing is required.** Maintaining network presence may include obtaining and/or defending an assigned interface or network address, responding to requests from other nodes on the network, or sending periodic network presence messages to the network all while in the sleep state. In this fashion, presence of the computer, its network services and applications, is maintained even though the computer is in sleep.

We needed a standards organization

Considered and rejected

- IEEE: Institute for Electrical and Electronic Engineers
  - Most active at 'lower layers'
  - … and slow
- IETF: Internet Engineering Task Force
  - Correct layers
  - … but not focused on energy problems
  - … proxying does not define a new protocol
- DMTF, IEC, JTC1, Energy Star, Green Grid, ….
  - None a good match

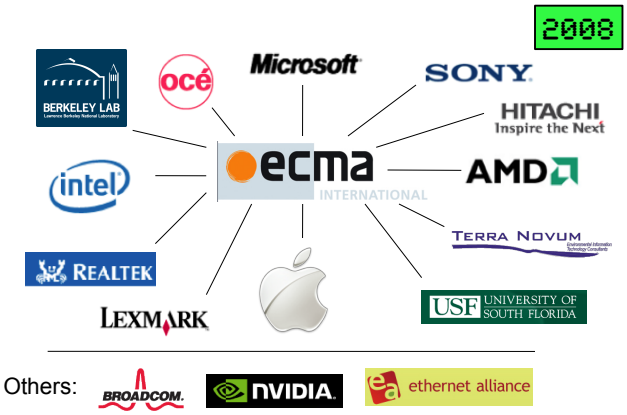
Selected Ecma International

- Already engaged with Energy Star
- Almost all key companies already a member
- Nimble and flexible

ecma INTERNATIONAL

Ecma Standard Participants

TC32-TG21 → TC38-TG4



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Network Layers

OSI Model	Condensed	Function
7-Application 6-Presentation 5-Session	Application	Applications & other presence
4-Transport 3-Network	Network	Data across network and basic presence
2-Data link 1-Physical	Link	Data across links

Internet traffic carried in "packets"

How does a proxy handle each packet?

- Four possible actions / activities – protocol dependent
  - Ignore
  - Automatic reply
  - Auto-generate packets
  - Wake
    - Quick reply then resume sleep (e.g. 10 s total)
    - Begin ongoing activity
- (requires some context information from PC)

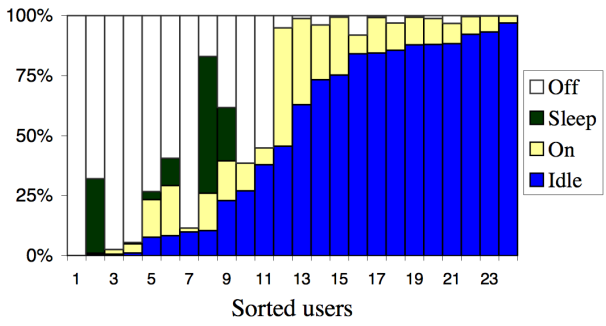
Trace analysis to inform standards development

- Collaboration with Intel Research Berkeley, U.C. Berkeley, International Computer Science Institute
- Dataset analyzed
  - ~250 PCs, 5 weeks of data each, desktops & notebooks
  - User input status (each 1s period)
    - Times > 15 minutes since user input designated "idle"
  - Full network traces
    - all incoming & outgoing packets
  - ~ 500 GB of data

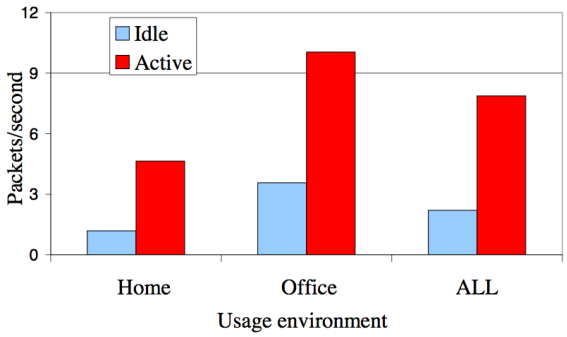
Trace analysis explored traffic and protocols

- Network traffic characteristics during idle times
- Protocol presence and frequency
- Protocol meaning and function
- Candidate proxy architectures
- Savings potentials from each proxy approach
- Traffic characteristics
  - Broadcast, Multicast, Unicast
  - Inbound, Outbound
  - At office, In home, Elsewhere

Desktop PC usage dominated by idle



Proxy needs to handle < 10 packets/second



Overall, 2-3 packets per second in idle (average)

Proxy must handle common broadcast protocols

Office		*Home*	
Protocol	**% of traffic**	**Protocol**	**% of traffic**
ARP	46.13	ARP	42.56
NBNS	22.89	SSDP	19.63
IPX	10.12	NBNS	9.48
NBDGM	5.91	CUPS	5.6
LLC	3.28	LLC	4.4
ANS	2.85	UNISTIM	4.07
RPC	2.46	IPX	3.8
BOOTP	2.01	NBDGM	2.3
NTP	1.13	BOOTP	1.02
Other	3.22	Other	7.14
Total	**100**	**Total**	**100**

Proxy must handle common unicast protocols

Transport Protocol	**Session Protocol**	**% of traffic**	
TCP		94.73	
	DCE/RPC		24.91
	NBSS		14.85
	HTTP		12.31
	TPKT		3.82
	SSL		2.68
	VNC		2.45
	Other		33.71
UDP		3.75	
	DNS		1
	Other		2.75
ICMP		1.29	1.29
Other		0.23	0.23
Total		**100**	**100**

Conclusions on how to handle specific protocols

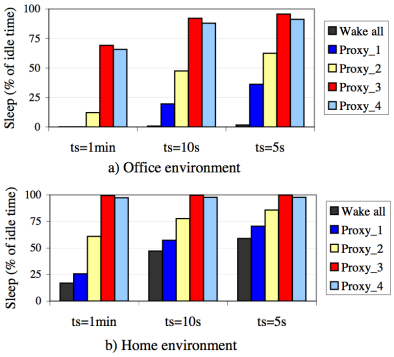
- "Don't wake" group and "don't ignore" group

Ignorable	HSRP, PIM, ARP (for others), IPX, LLC, EIGRP, DHCP	
Mechanical Response	Protocol	State
	ARP	IP address
	NBNS	NB names of machine and local services
	SSDP	Names of local plug-n-play services
	IGMP	Multicast groups the interface belongs to
	ICMP	IP address
	NBDGM	NB names of machine and local services. Ignores pkts. not destined to host, wakes host for rest

Four candidate proxy designs

- Proxy 1
  - Ignore what can
  - Wake on everything else
- Proxy 2
  - Proxy 1 *plus* also issue routine responses
- Proxy 3
  - Issue routine responses;
  - Wake only on specified protocols
- Proxy 4
  - Proxy 3 *plus* also wake for predetermined activity

All proxy designs save some energy



Proxy_1 and _2 are "transparent"

- functionally more robust
- save less energy
- more vulnerable to changes in traffic

However – be wary of more than small amounts of non-sleep time

Trace analysis conclusions

- Even simple proxies save enough to be compelling
  - But issue of number of wakes/day
- More sophisticated, but manageable, proxies save most PC energy use
- Best approach is to ignore unknown traffic
- Home and office network environments significantly different
  - But can expect home environment to become more crowded

Nedevschi, Sergiu, Jaideep Chandrashekar, Bruce Nordman, Sylvia Ratnasamy, and Nina Taft 2009. "*Skilled in the Art of Being Idle: Reducing Energy Waste in Networked Systems.*" Proceedings: 6th USENIX conference on Networked Systems Design and Implementation.

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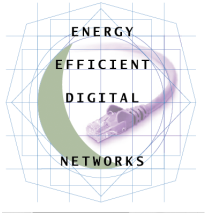
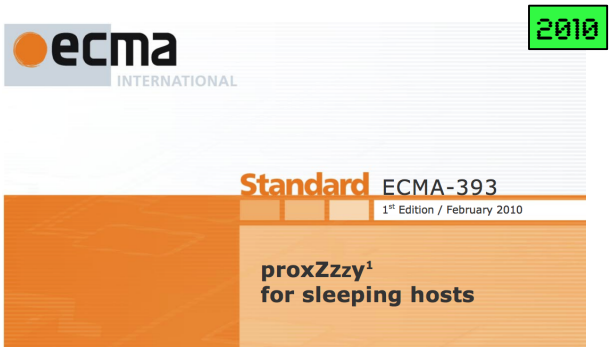


Ecma standard finalized



In process for adoption by International Electrotechnical Commission (IEC)

Ecma standard covers all three "layers"

	Requirements Implemented
Link	Media (802.3, 802.11)
Network	IPv4 ARP
	IPv6 Neighbor Discovery
	DNS
	DHCP
	IGMP
	MLD
Application	Remote Access using SIP and IPv4
	Remote Access using Teredo for IPv6
	SNMP
	Service Discovery using mDNS
	Name Resolution with LLMNR
	Wake Packets

The standard met our goals

- Intended for PCs and any "PC-like" device
- Establishes a floor of functionality, not a ceiling
- Aims to enable large majority of PC users to use sleep without breaking applications (their own or IT admin)
- Does not limit the location of proxy
  - –Internal or External
- Supported by all industry members of committee

Nordman, Bruce, and Ken Christensen, *"Greener PCs for the Enterprise,"* IEEE IT Professional, Vol. 11, No. 4, pp. 28-37, July/August 2009.

Nordman, Bruce, and Ken Christensen 2010. "*Proxying: The Next Step in Reducing IT Energy Use.*" IEEE Computer (Green IT column), January 2010.

Apple sells proxying

- External proxy announced, June, 2009
  - Base station, other PC, backup device
- Internal proxying shipped starting December, 2009
  - Now called "Wake on Demand"

More efficient file sharing.

The Bonjour technology in every Mac makes file and media sharing virtually effortless. Now Bonjour in Snow Leopard makes sharing more energy efficient. If you have a computer in your home or office that shares files — like media files for your Apple TV — you have to leave the computer on all the time, which isn't very energy efficient. With Snow Leopard and a compatible AirPort Extreme or Time Capsule base station, however, your computer can go to sleep yet continue to share its files with other computers and devices, waking when you need it and sleeping when you don't.

Multiple companies provide hardware for proxying

More research is needed

- Measured data from actual deployment in field
- External proxy standard
  - Network equipment or proxy server
  - Need host ↔ proxy protocol
- Host unaware proxy
- Guidance on how to develop proxy-friendly protocols
- Security issues
- Embodying power state in network protocols

Conclusions

- Remember our hypotheses
  - Proxying can address a key barrier to reducing PC energy use
  - Proxying can be specified
  - Proxying can be brought into products
- Proxying could save about half of PC energy use
  - Several $ billion/year in U.S. alone
  - Also adds functionality for those who don't save energy
  - More savings in printers, game consoles, set-top boxes, …
- Electronics fundamentally different from other end uses
- Networks pose unique challenges and opportunities
  - Under-appreciated by energy policy and research
- LBNL is the leader in this area — continuing to do so should be a priority

Thank you