ICT, Networks, and Energy: The Energy Perspective

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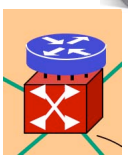
Overview

Electronic Networks

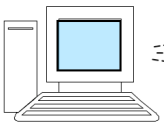
- How much energy does "The Internet" use
- Some things we know
- How to think about Networks and Energy
- Current projects
- Summary

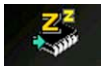
(my other topic: **Building Networks**)



Overview

- Think Broadly about Networks ….





How much energy does The Internet use?

1999

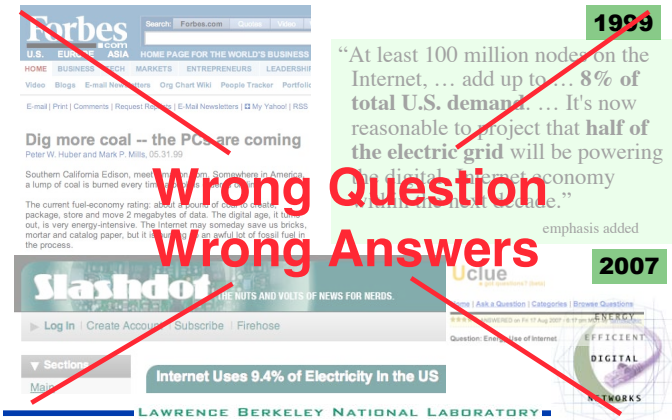
"At least 100 million nodes on the Internet, … add up to … **8% of total U.S. demand**. … It's now reasonable to project that **half of the electric grid** will be powering the digital- Internet economy within the next decade."

emphasis added

2007

Internet Uses 9.4% of Electricity In the US

How much energy does The Internet use?



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emphasis added

2007

Wrong Question

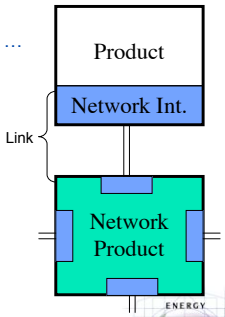
Wrong Answers

Some questions worth asking

- How much energy does all **network** equipment use? … **telecom** equipment? … **edge** devices?
- How much energy does network connectivity induce in edge devices?
- [How much energy does IT avoid?]
- Where is all this headed?
- How much can we reasonably save in network eqt.? … in edge devices?
- What are research and implementation priorities?

Networks and Energy

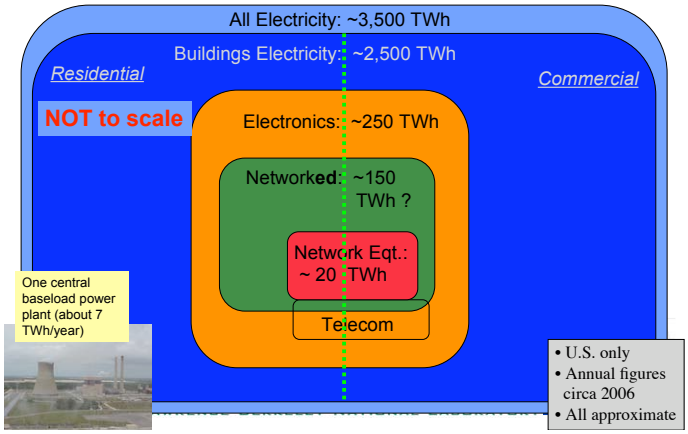
Network equipment ….
Routers, switches, modems, wireless APs, …
… vs **networked** equipment
PCs, printers, set-top boxes, …



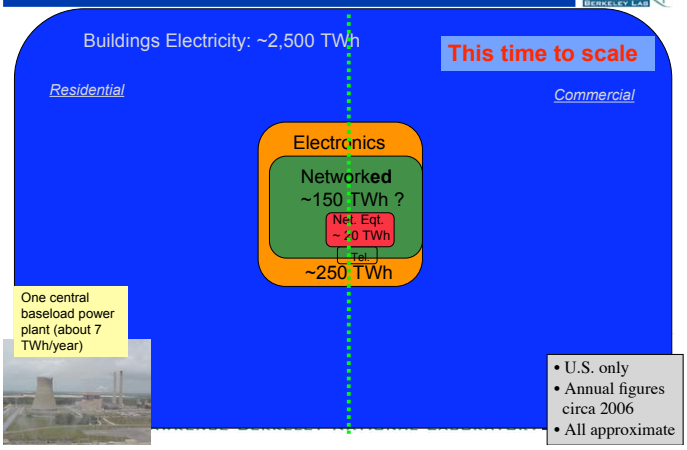
How networks drive energy use

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

Network electricity use in context



Network electricity use in context, cont.



How to think about energy quantities

Our needs only require approximations

1 year = 8,760 hours	~ 10,000 hours
1 kWh costs $0.09	~ $0.10
1 W for 1 year	~ $1
1 TWh = 1 billion kWh	~ $100 million
U.S. annual consumption	~ 3,500 TWh
… buildings portion	~ 2,500 TWh

How much energy does network equipment consume?

(Bruce's best estimate)	*$billion*	*TWh/year*
Telecom	*$0.8*	*8.*
Data center	**$0.20**	**2.0**
Residential	**$0.73**	**7.3**
Commercial (office)	**$0.88**	**8.8**
Subtotal	$1.80	18
IP Service providers (access, metro, core)	*< ?*	*< ?*

Total: ~20 TWh/year

- **All of these figures rough estimates for 2006**
- *None of this includes cooling or UPS*
- *$0.10/kWh used for convenience*

- **U.S. only — Global figures probably 3-5 times larger**

So……

- Network equipment ~ 1% of buildings electricity
- All electronics ~ 10% of buildings electricity

So……

- Network equipment ~ 1% of buildings electricity
- All electronics ~ 10% of buildings electricity

BUT……

- 1% of a very large number …..

…..is still a very large number

Things we know: Energy consumption is at edge

- Network equipment < 10% of all electronics
- Most electronics already networked
- More electronic — and non-electronic — devices getting networked
- Network *induced* consumption > all direct
- Network equipment energy will grow …
  … but other electronics will grow faster

Things we know: Utilization is low

- *Data networks are lightly utilized, and will stay that way*, A. M. Odlyzko, *Review of Network Economics*, 2003

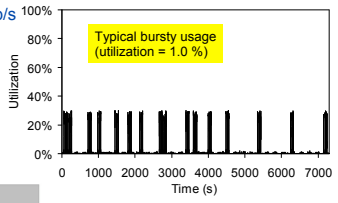
Network	Utilization
AT&T switched voice	33%
Internet backbones	15%
Private line networks	3~5%
LANs	1%

Low utilization is norm in life — e.g. cars

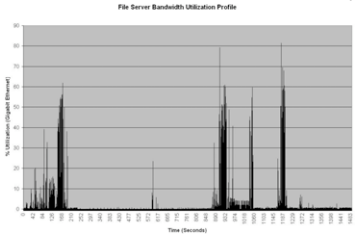
- Average U.S. car ~12,000 miles/year = 1.5 miles/hour
- If capacity is 75 mph, this is **2%** utilization

Things we know: Utilization is low, cont.

- Snapshot of a typical 100 Mb/s Ethernet link *(Singh)*



- File server link utilization (daytime) *(Bennett, 2006)*

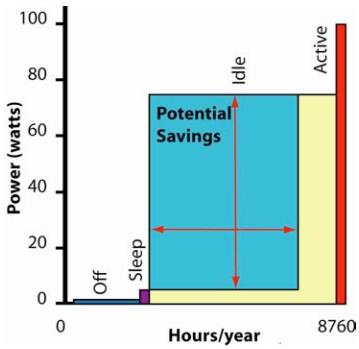


Conclusions (for edge links only)

- Bursty
- Very low average utilization

Things we know: Edge device energy is mostly idle

Core Fact: Most PC energy use occurs when no one present



All time for year sorted by power level

Most of time when idle, could be asleep

PC savings potential is **most** of current consumption

Similar patterns apply to set-top boxes, printer, game consoles, …

Things we know: Economics matter

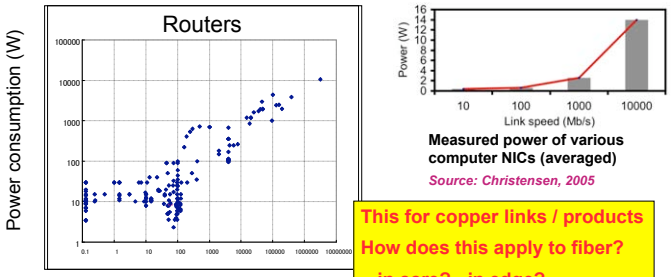
- Most energy efficiency investments save >> first cost

*"Not a free lunch, but one you get paid to eat"**

- Rampant market failures
  - Split incentives between designers, purchasers … purchasers, energy cost payers
  - Lack of information
  - Inability to use efficiency information
- Business-as-usual leads to large energy waste

**paraphrased from Amory Lovins*

Things we know:
Speed costs energy / power



Measured power of various computer NICs (averaged)

Source: Christensen, 2005

This for copper links / products
How does this apply to fiber?
- in core? - in edge?

Source: METI, 2006

Energy cost is a function of capacity, not throughput

Things we know:
IP will go everywhere

- IT equipment - IP already universal

- IP for phone calls (VOIP)
- IP for TV (IPTV)
- IP for consumer electronics generally
- IP for buildings (lighting, climate)
- IP for …..

Some of this will not transit Internet

How should we think about networks and energy?

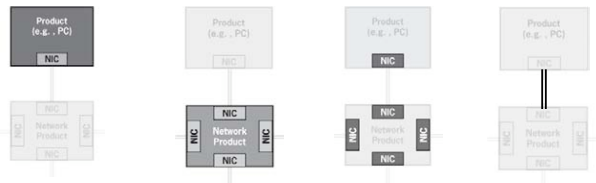
Approaches / Focus

- Device
  - AC*-powered products
- Link
  - Capacity, usage, distance, technology
- Throughput
  - Traffic totals, patterns, distribution
- Application / Protocol
  - Drivers of infrastructure, edge devices
- Context
  - In-use / not, time-sensitive / not, etc.

Essential to use all approaches simultaneously

Efficiency Approaches

Product Focus	Network Product Focus	Interface Focus	Protocol / Application Focus



Examples:

Proxying **Energy Star** Energy Efficient Ethernet **CE**

Need all approaches

Finding Energy Savings Opportunities

Sample approaches

- Relax assumptions commonly made about networks
  - –when feasible (rarely in core); mine wireless technology
  - –these assumptions drive systems to peak performance
    - average conditions require less energy
    - many assumptions tied to latency
- Design for average condition, not just peak
  - –rely on data about typical use
- Use Network to gather info about savings opportunities
- Use Network to enable edge device savings

LBNL Projects

Energy Efficient Ethernet

- Link savings

Network Connectivity "**Proxying**"

- Edge device savings

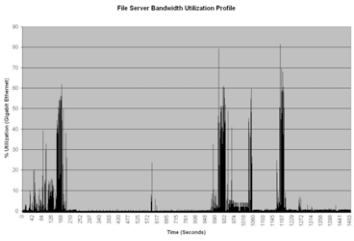
Efficiency Specifications for Network Equipment

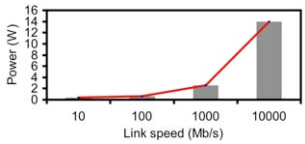
- Network equipment savings

Consumer Electronics

- Edge device savings

Adaptive Link Rate …





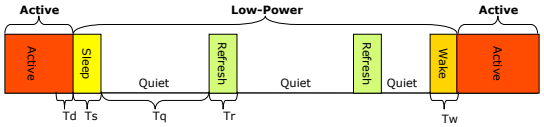
Observations

- Most of time, full link capacity not needed
- Notebooks already dropped link rate in sleep

Proposal (LBNL & USF)

- Enable changing link rate **quickly** in response to traffic levels *(**ms** not s)*

… Energy Efficient Ethernet



- IEEE 802.3az created to standardize EEE
- Standards process began with ALR; eventually settled on alternate method "Low Power Idle"
  - Stop transmitting between packets
  - Switch now takes ***micro***seconds
- Standards process needs about 1 more year
  - Goal to get EEE technology into ALL Ethernet network hardware globally over next few years

Energy Efficient Ethernet

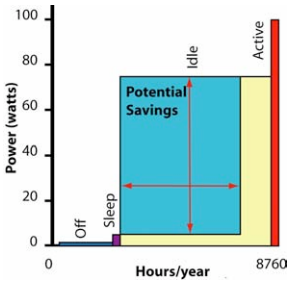
IEEE

IEEE 802

ENERGY STAR

Network Connectivity "Proxying"

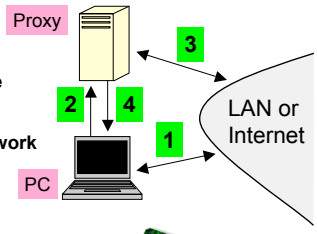
- Enable large majority of PC users to use sleep without breaking their own or IT admin applications
  - At least 80%. > 90% better. > 95% or > 98% even better.
- Enable both current and emerging common applications
- Enable standard to be used directly in (or easily adapted for) printers, set-top boxes, game consoles, etc.



Proxying, cont.

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**



Proxy can be internal (NIC), immediately adjacent switch, or "third-party" device elsewhere on network

Proxy does: ARP, DHCP, TCP, ICMP, SNMP, SIP, ….

Efficiency Specs for Network Equipment

Today:

- Network equipment a growing electricity use in all sectors
- Companies increasingly claiming energy efficiency as a feature
- No current test procedures (no good ones)
- Very few efficiency specifications
- Little knowledge of networks in energy community

Efficiency Specs for Network Equipment, cont.

LBNL project:

- Estimate total energy use of network equipment in U.S.
  - –Approximately 1% of total
- Identify product types with largest comsumption, largest potential savings, and ease of rating for efficiency
- Work with industry to develop standard test procedures
- Create community of interest on topic
- Hand off to Energy Star for spec process

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Research Questions: Networks & Energy

- Should low link utilization lead to any powering down of links?
- How much savings can be leveraged by introducing more latency? (when OK for application)
- Should power state be exposed to the network?
  - Embodied in protocols
  - Distinct sleep state with reduced network connectivity?
- Should a document of guiding principles be developed for protocols and other standards?
- Will security features or concerns sometimes trump energy efficiency?
- What intelligence in network should support energy efficiency in network equipment? in edge devices?

Summary – Electronic Networks

- Network energy use neither huge nor small
  - induced larger than direct
- Most energy use is at the edge
- Large savings possible - many approaches needed
- Most opportunity is at non-peak conditions
- Energy raises network architecture questions

Key collaborator: Ken Christensen, University of South Florida

Electronics as an End Use

- Electronics are an end use of electricity

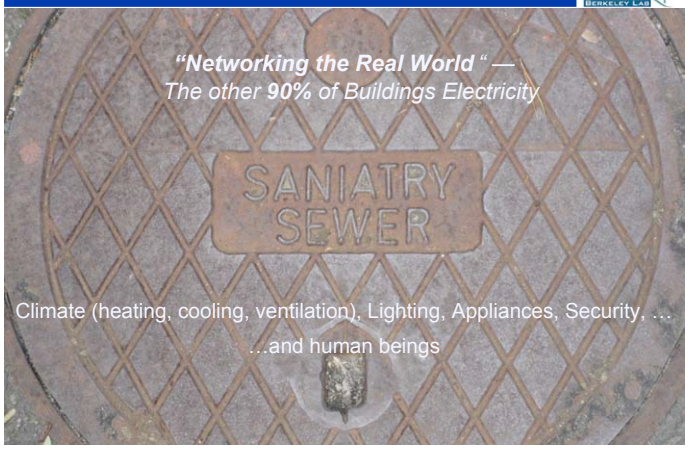
  *"Devices whose primary function is **Information** (obtain, store, manage, present)"*

  –Includes both Information Technology (IT) and Consumer Electronics (CE)

  –Much of this digitally networked already

- Conventional end uses (HVAC, lighting, appliances, …) all based in physics
- Electronics based in information
- (don't forget Miscellaneous)

Building Networks



What about the "Smart Grid"

- If the "Smart Grid" stops at the meter:
  - I have nothing to say
- If the "Smart Grid" extends through the meter:
  - This is a very bad idea that will impede improvements in grid and in buildings
  - The meter is our friend

Thank you!

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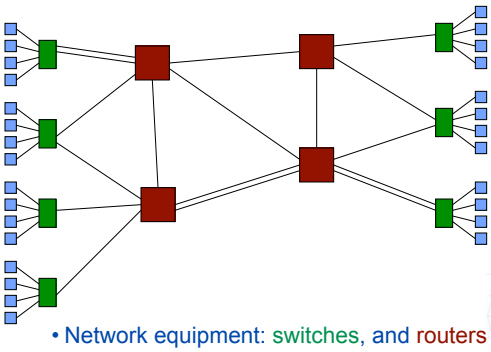
Network Structure

- Edge devices: PCs, servers - Displays, storage, phones, …



- Network equipment: switches, and routers