**Slide 1: Overview**

- Why care?
  - Electronics Energy Use
  - Things we know
  - Efficiency Opportunities
  - Building networks

**Networks a principle theme / example**

**Slide 2: Why care about electronics, energy?**

- Core
  - Energy
  - Carbon
  - $$\text{\$600 billion}$$
- Extreme conditions
  - Power deserts (no mains)
  - Power oceans (datacenters)
  - Power ponds (e.g. notebook)

**Slide 3: What the real world tells us about saving energy in electronics**

- What are “electronics”
  - “Devices whose primary function is information”
    - Computation, communication, storage, display
- Potential savings derive from actual use
- What is relevant in the real world besides circuits
  - People, organizations, economics, public sector, ...
- How to cause future savings

**Slide 4: How much energy does The Internet use?**

“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.”

**Slide 5: First, Think Broadly ....**

**Slide 6:**

- Forbes
- Dig more coal = the PCs are coming
- Slashdot
- Internet Uses 8.4% of Electricity in the US
How much energy does The Internet use?

“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 economy.”

Some questions worth asking

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

Wrong Question
Wrong Answers

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 induced consumption > all direct

Electronics / network electricity use

buildings electricity: ~2,700 TWh

data centers
servers 22.5
storage 2.7
network 2.7
telecom 10

~290 TWh/year

what is in that 290 TWh/year?

<table>
<thead>
<tr>
<th>Data Centers</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.5 Servers</td>
<td>Information Technology</td>
</tr>
<tr>
<td>2.7 Storage</td>
<td>7.3 Modem, router, etc.</td>
</tr>
<tr>
<td>2.7 Network</td>
<td>2.6 Imaging</td>
</tr>
<tr>
<td>10 Telecom</td>
<td>21 PC, Desktop</td>
</tr>
<tr>
<td>7.7 monitors</td>
<td>2.8 PC, Notebook</td>
</tr>
<tr>
<td>37.9 TOTAL</td>
<td>7.7 Monitors</td>
</tr>
</tbody>
</table>

consumer electronics

6 Reel. Electronics
5 VCR
4.4 DVD player
1.6 Security system
51 TV, Analog
16 TV, Digital
3.3 Clock Radios
10 STB, Cable
9 STB, satellite
6.1 Stereo
6.2 Compact Audio
2.2 Home Theater
0.7 Portable Audio

161.9 TOTAL

This time to scale
**Things we know:**

**Utilization is low**

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

<table>
<thead>
<tr>
<th>Network</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT&amp;T switched voice</td>
<td>33%</td>
</tr>
<tr>
<td>Internet backbones</td>
<td>15%</td>
</tr>
<tr>
<td>Private line networks</td>
<td>3–5%</td>
</tr>
<tr>
<td>LANs</td>
<td>1%</td>
</tr>
</tbody>
</table>

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:**

**Edge device energy is mostly idle**

- Typical bursty usage (utilization = 10%)

**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, for TV, printer, ...

**Things we know:**

**Edge device energy is mostly idle, cont.**

- Annual energy consumption above idle level
  - Servers: < 5%
  - Desktop PCs: < 3%
- IP phones: Active consumption < 5% of total
- Set-top boxes: < 50% (probably much less; depends on defn.)
- VCRs < 50% playing or recording

**Things we know:**

**Speed costs energy / power**

Source: Christensen, 2005

Energy cost is a function of capacity, not throughput
**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

**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
    - payers, users
  - Lack of information
  - Inability to use efficiency information

- Business-as-usual leads to large energy waste

*paraphrased from Amory Lovins

**Things we know:**

**People (users) matter**

- Only reason electronics exist

**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, nodes
- **Context**
  - In-use / not, time-sensitive / not, etc.

Essential to use all approaches simultaneously

**Efficiency Approaches**

**Examples:**

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

Need **all** approaches

**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
What is a building network?

- People
- Light Sources
- Light modifiers
- Thermal sources, ventilation
- Displays
- Sensors
- Appliances

really good

What is a building network?

- Dynamic
- Robust
- Efficient

Buildings Networks

- Needs
- Design building networks for next century
- Embrace Internet Protocol and standard network tech.
- Adopt goal of “Universal Interoperability”
  - Across building types, geography, end uses, people, time, …
- Create standard “dictionary” of real world
  - Building elements, ideas, characteristics, actions, …
- Be prepared to jettison any / all existing technology

Buildings Networks

“Networking the Real World” — The other 90% of Buildings Electricity
Climate (heating, cooling, ventilation), lighting, appliances, security

- Building Network architecture not being done with sophistication and care that went into Internet design.
- Result may be burden us with bad design for decades to come.

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, ….
Collective Action

• Common in electronics
  • Grid
• Technical standards
  • Mechanical, electrical, software
• Essential for savings
  • Public policy
  • Technical standards
  • Industry consortia

• Standards can mandate or prohibit efficiency features

Summary

• Common “wisdom” on electronics and energy may not be valid
• No substitute for empirical data
• Networks increasingly important
• Utilization is low
• Building networks a key priority

Thank you!

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