Network Standby - Toronto

Energy Efficient Ethernet

Energy Efficient Ethernet (EEE)

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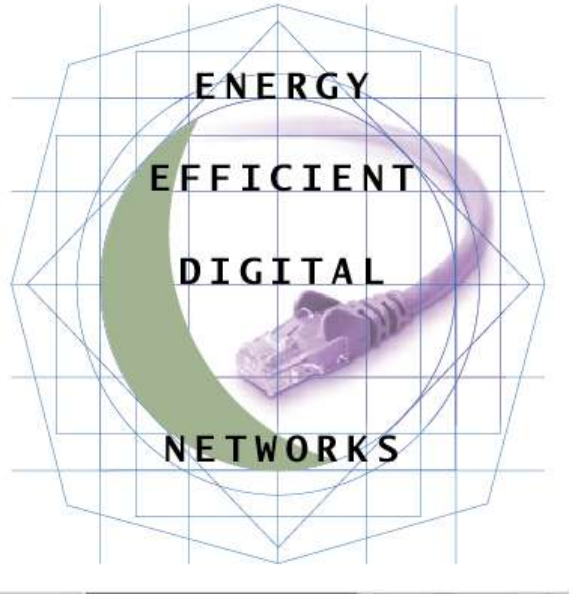
Overview

- Networks and energy
- Ethernet basics
- EEE technology and development
- EEE savings
- Lessons learned



What are “electronics”

“Devices whose primary function is information”

– Computation, communication, storage, display

Major categories:

Phones

Audio/visual PCs

Network equipment

Servers Storage

Printers / copiers

In U.S., all electronics > 10% of buildings electricity

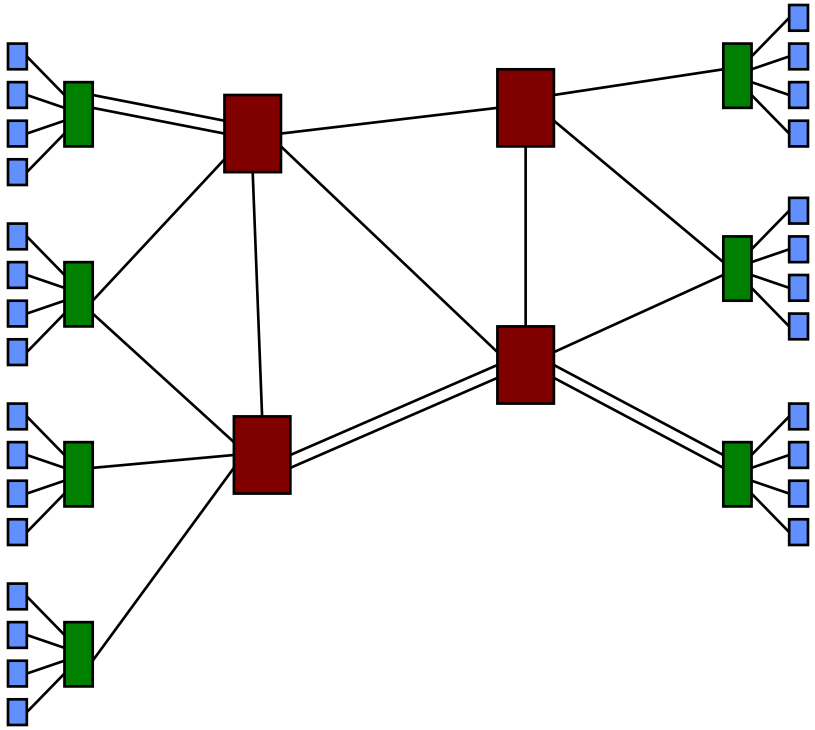
What is a network?

Mechanism for arbitrary communication among a set of entities (hosts)

Internet Protocol networks use **switches** and **routers**

Between network nodes are data links

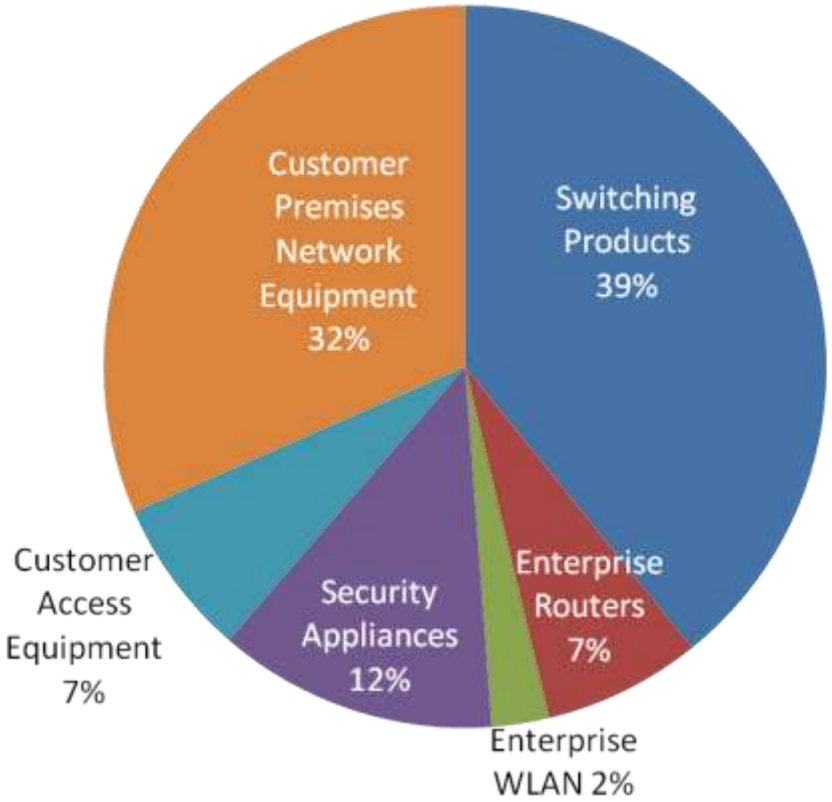
Many links use Ethernet technology – IEEE 802.3



In U.S., all network eqmt. about 1% of buildings electricity

Network equipment energy use (U.S.)

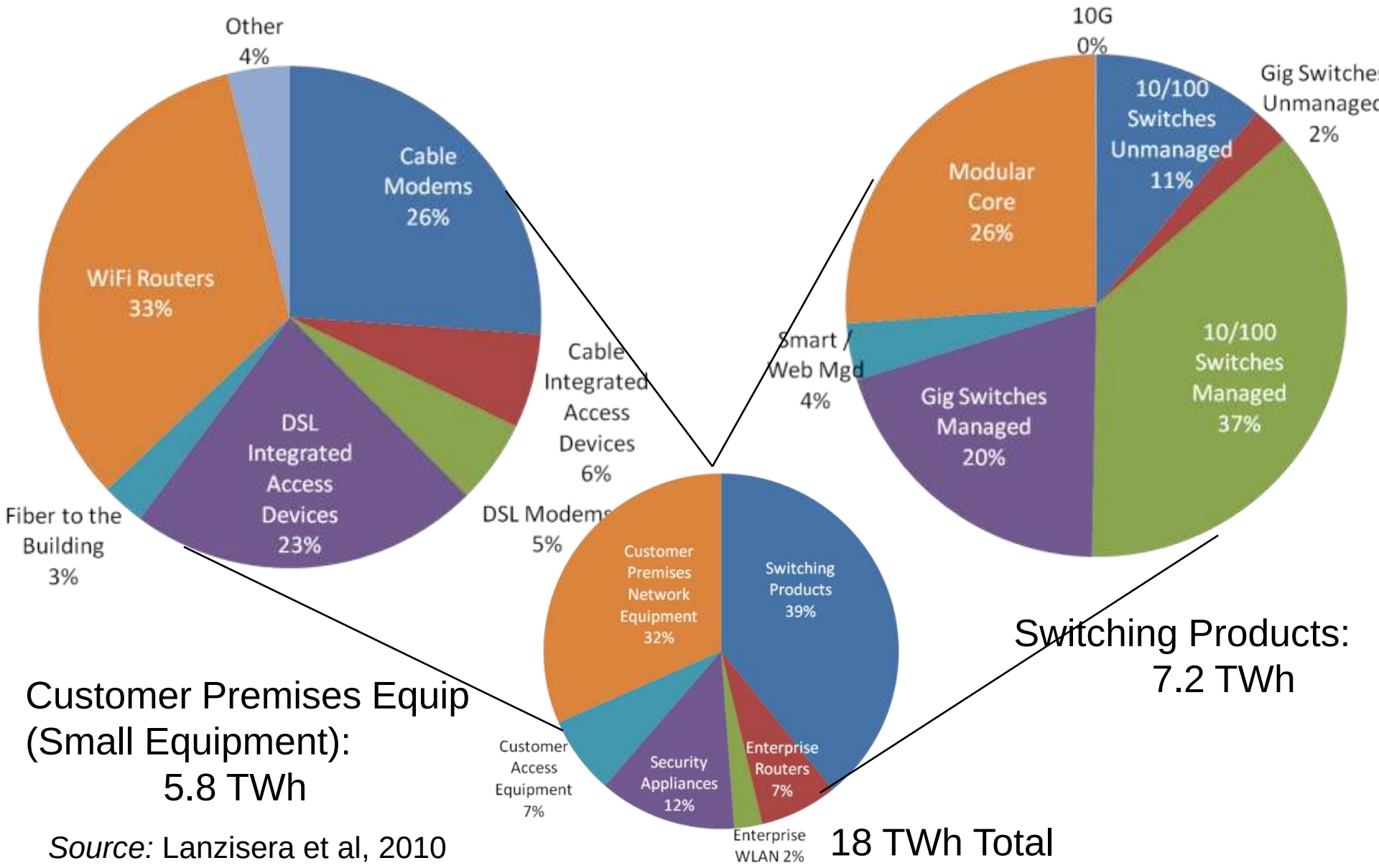
- **2008 Total: 18 TWh**
- **Growth between 2007 and 2008: 10%**
- **Forecast annual growth rate: ~6%**



Sources:
Infonetics Market Data, 2003-2012
FCC Broadband Market Data 2007-08
Tolly Group Power Measurements
LBNL Power Measurements
AT&T Market Estimates
Industry Data Sheets
Survey of Consumer Electronics Stores

Source: Lanzisera et al, 2010

Network equipment energy use (U.S.) **(2)**



Switching Products:
7.2 TWh

Customer Premises Equip
(Small Equipment):
5.8 TWh

Source: Lanzisera et al, 2010

18 TWh Total

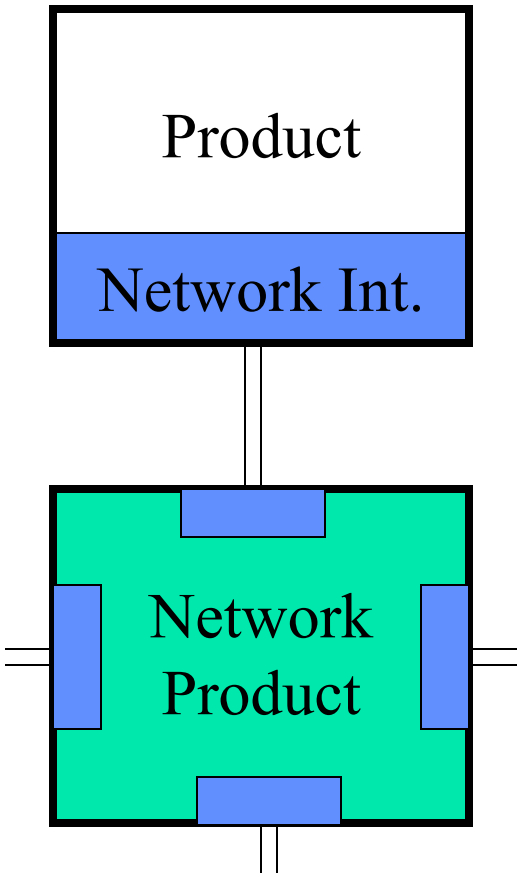
Networks and energy

Network equipment ….

Modems, routers, switches, wireless APs, …

… vs network**ed** equipment

PCs, printers, set-top boxes, TVs, …

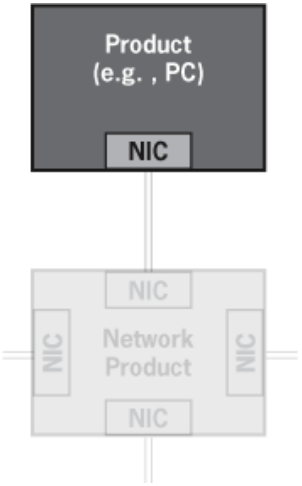


<u>How networks drive energy use</u>

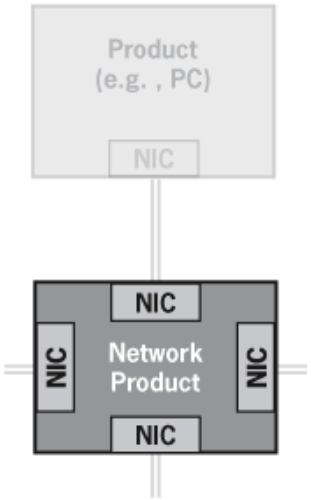
- Direct
  - Network interfaces (NICs)
  - Network products
- Induced in Network<u>ed</u> products
  - Increased power levels
  - Increased time in higher power modes (to maintain network presence)

Efficiency approaches in networks

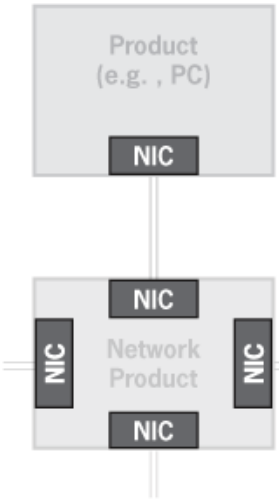
Product Focus



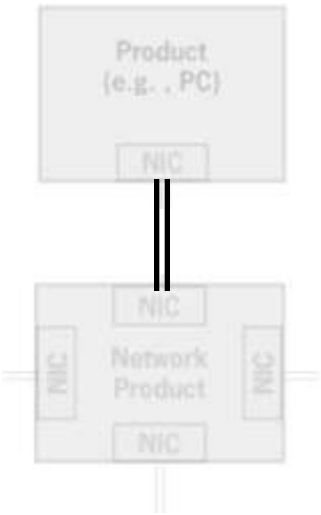
Network Product Focus



Interface Focus



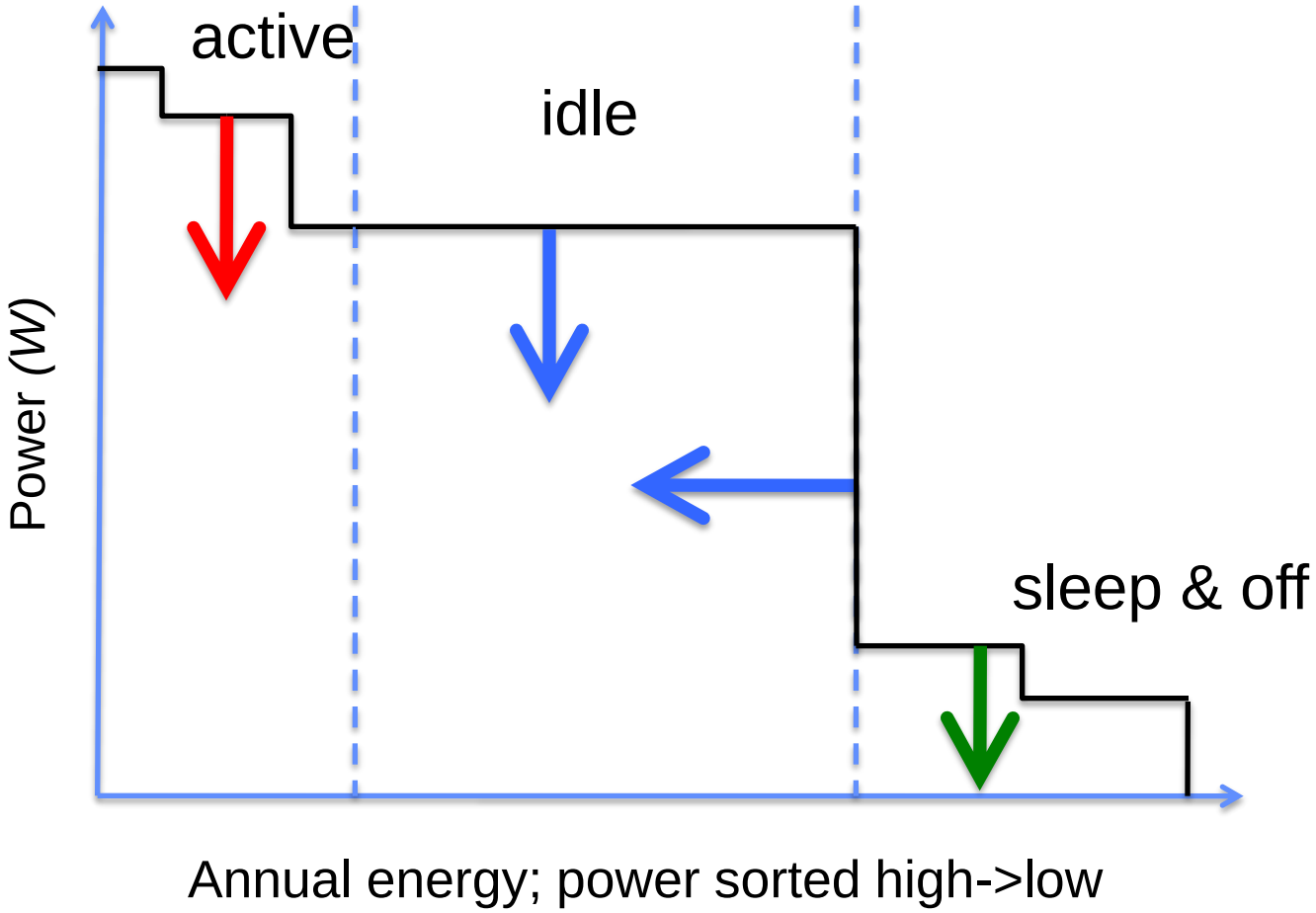
Protocol / Application Focus



EEE

Core methods to reduce electronics energy use

- **active power**
- **low-power mode power**
- **idle time or power**



Networks and energy principles

- The behavior on the network of one device can change the energy use of devices it is connected to
- In networks, technology standards play role that laws of physics do for other end uses of energy
- Network energy use is like an onion

Ethernet technologies

Speed	Comments
10 Mb/s	Original speed; originally shared medium
100 Mb/s	“Fast Ethernet”; still commonly used in homes and commercial buildings
1 Gb/s	Standard for PCs, etc.
10 Gb/s	Servers, network links
40/100 Gb/s	Servers, network links
Other	> 100 Gb/s, optical, backplane, automotive, …

Ethernet concepts

- Capacity – size of “pipe” (millions or billions of bits/second)
- Utilization – % of capacity actually used
- NIC – each end of link
- Link – data path NIC—wire—NIC
- Autonegotiation
  - At start-up, both NICs on a link inform other of capabilities and agree to use highest common rate, etc.

A starting point: Utilization is often low

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

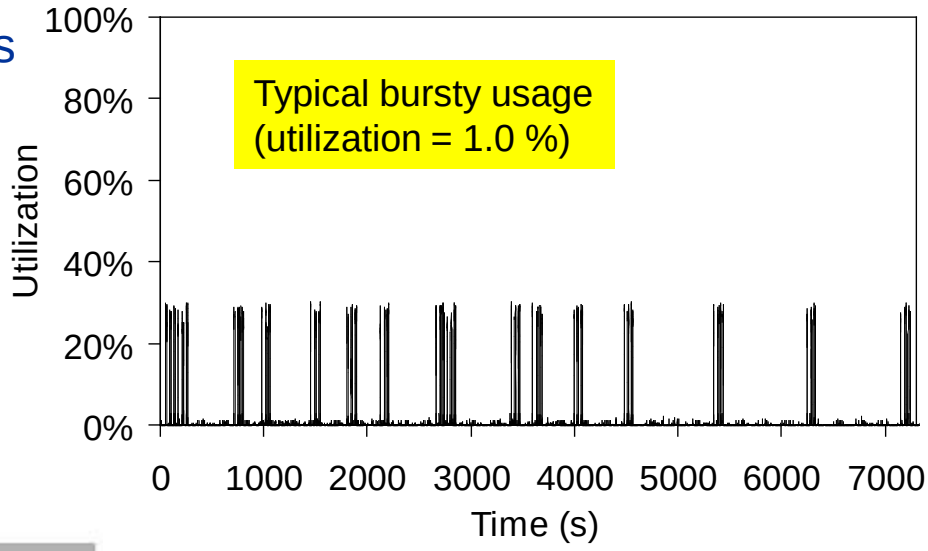
Network	Utilization
AT&T switched voice	33%
Internet backbones	15%
Private line networks	3~5%
Local area networks (LANs)	1%

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

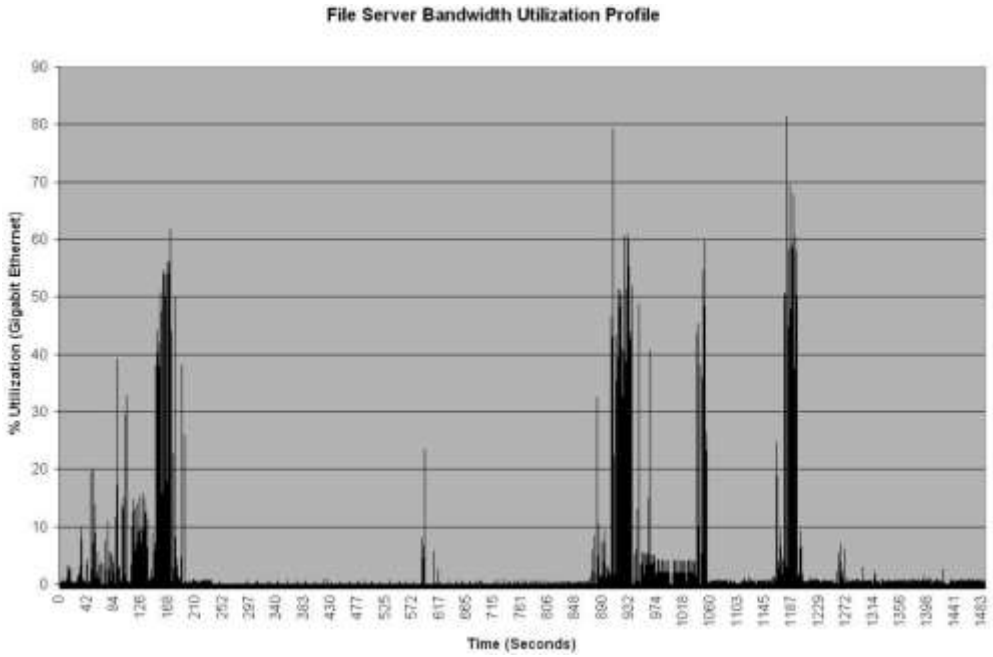
- Average U.S. car ~12,000 miles/year = 1.5 miles/hour
- If capacity is 75 mph, this is **2%** utilization

Utilization is low – for Ethernet

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



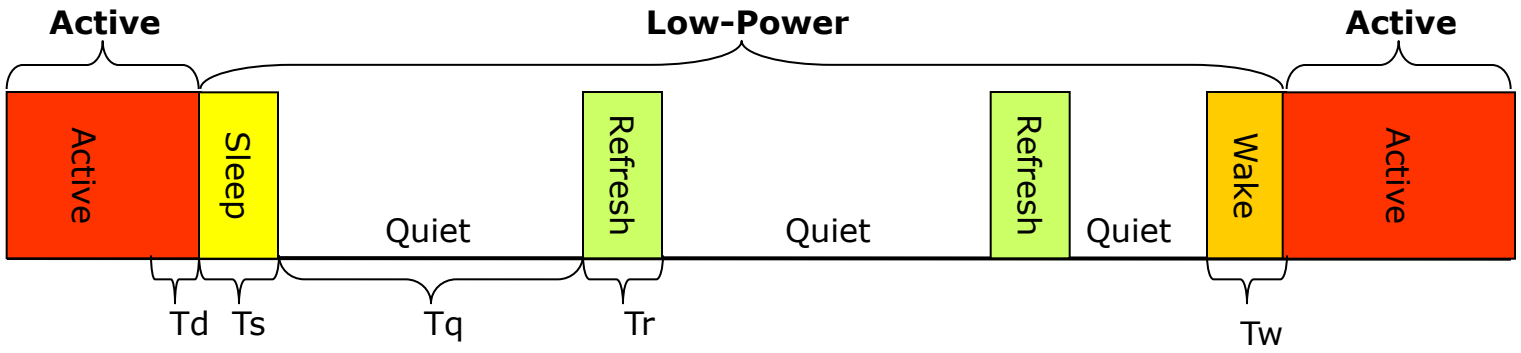
- File server link utilization (daytime) *(Bennett, 2006)*



Conclusions (for edge links only)

- Bursty
- Very low average utilization

EEE technology basis



- Added “Low Power Idle” capability to standard
- Stop transmitting between packet clusters
- Switch time measured in ***micro***seconds
  - Sleep, wake
- Refresh periods maintain link integrity
- When quiet, no transmit or receive
- Can initiate wake at any time
- Active functionality, power unaffected
- Applies to 100 Mb/s, 1 Gb/s, 10 Gb/s
- Discussions to extend to others

IEEE 802

IEEE

Energy Efficient Ethernet

EEE — terms

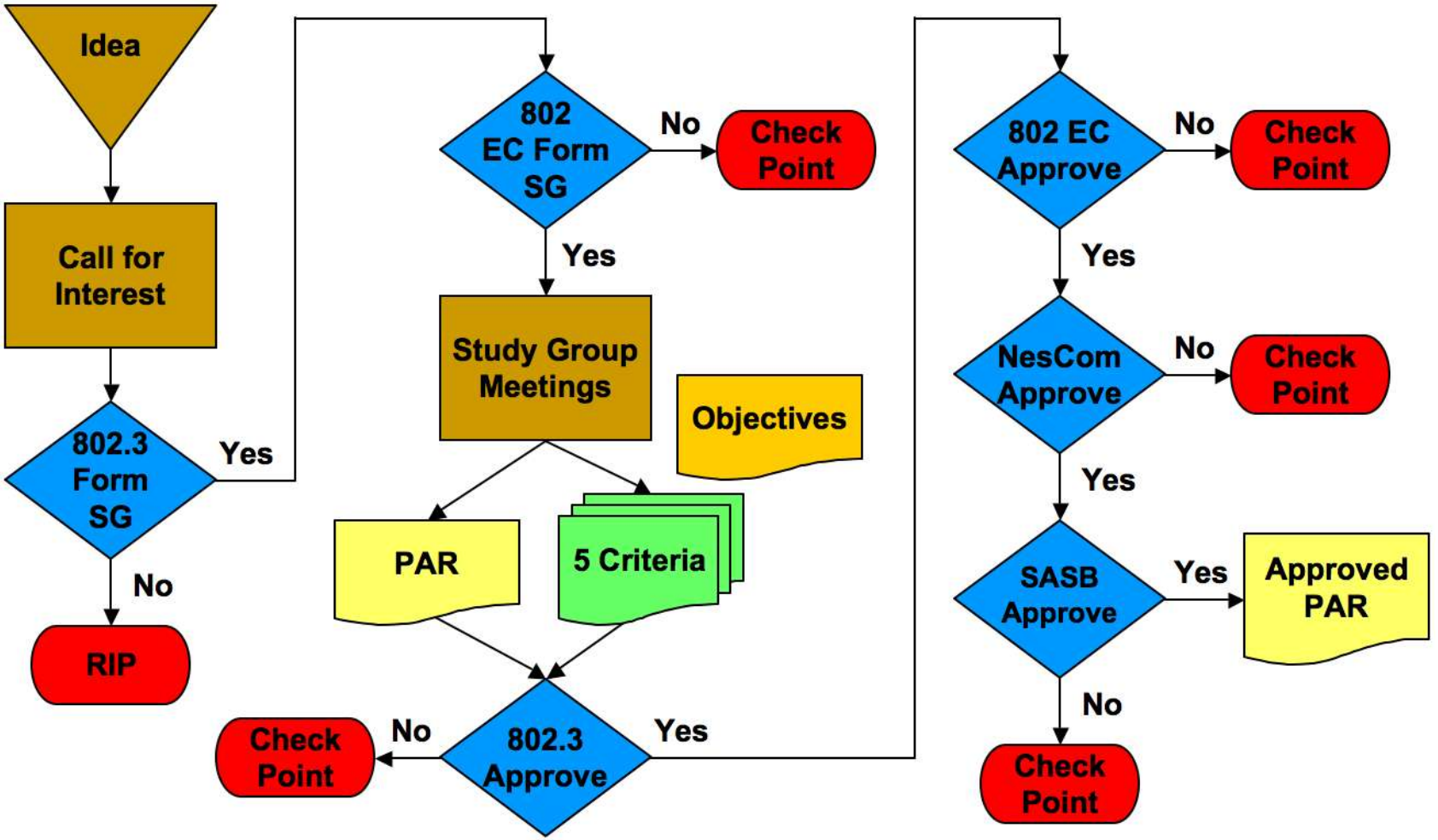
- “Energy Efficient Ethernet” not an official technical term
- Precise reference is to IEEE 802.3az
- Official title is:

  IEEE 802.3azTM/D3.0, 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.

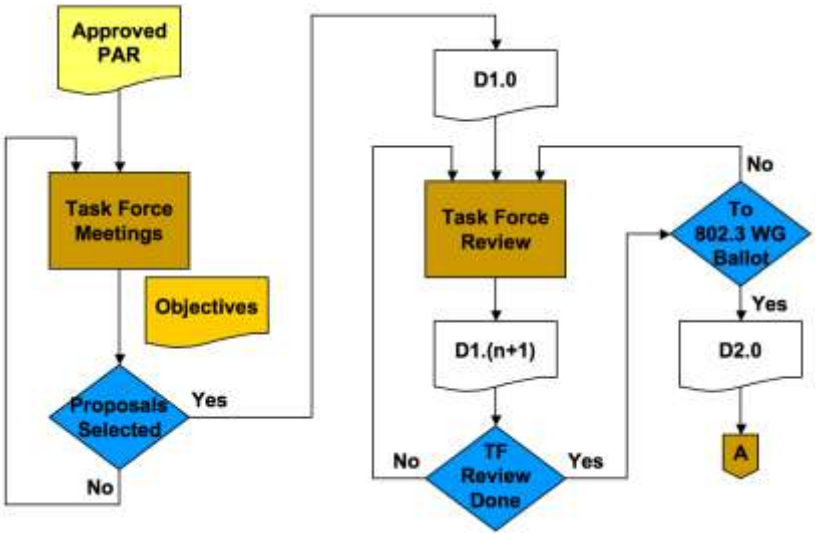
How did this happen?

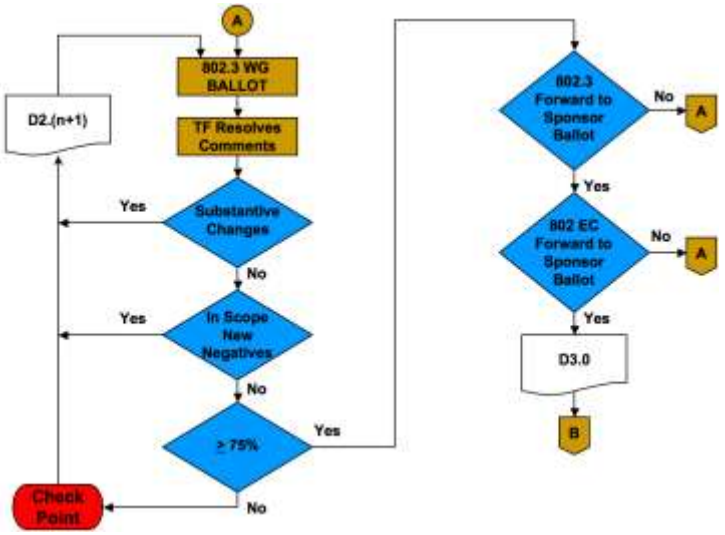
- 2004 – Origin – discussions around network proxying between Christensen and Nordman
- 2005 – Plenary presentation to IEEE (July)
- 2006 – Call for Interest (November)
- 2007 – Beginning of Study Group (January)
- 2007 – Study Group converted to Task Force (July)
- 2009 – Content substantially completed
- 2010 – Standard receives final approval (Sept.)
- 2010 – First products announced (NICs, network eqt.)
- 2012 – Wide availability

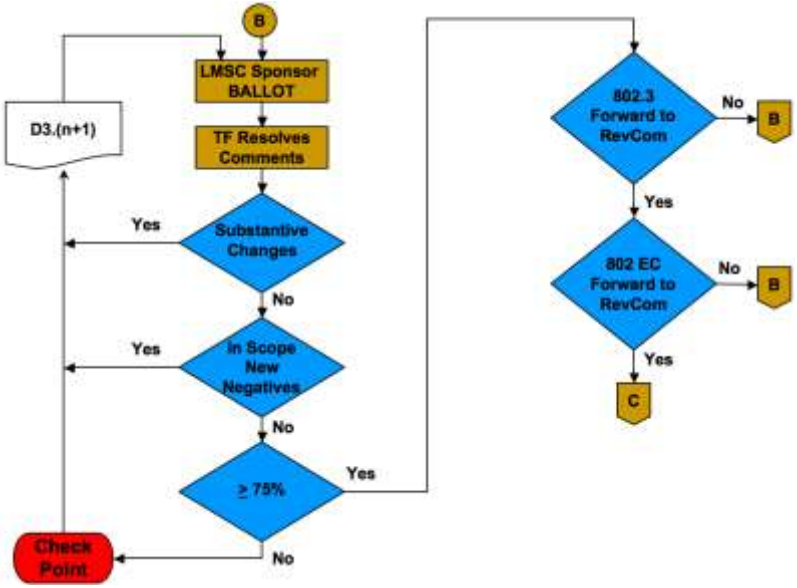
IEEE 802 Standards Process – Initial Steps

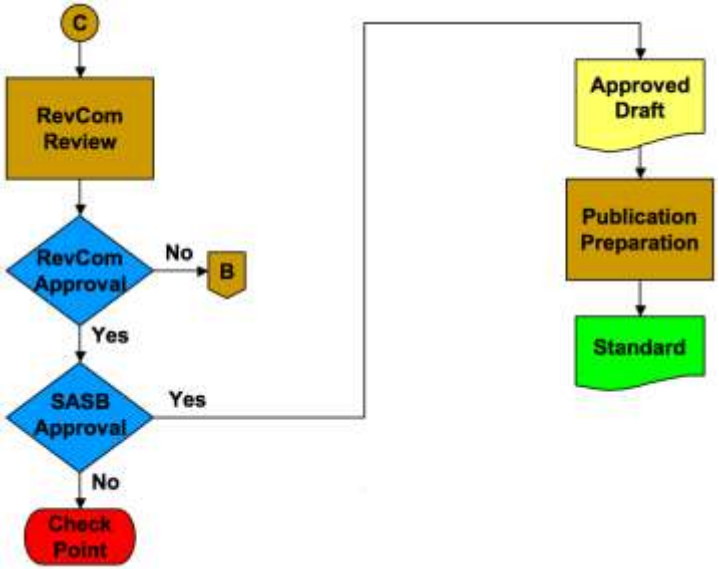


IEEE Standards Process – More Steps !









EEE - Savings

- Annual savings determined by
  - # of NICs deployed (sold and already in stock)
  - % in use at all
  - % of time each in use
  - Speeds capable; speeds actually used
- None of these well-known
- How precise is savings figure needed?

- 2007 estimate (full deployment) ($ million/year)

	1 Gb/s	10 Gb/s	Total
U.S.	300	300	600
Global	900	760	1,660

- 2010 estimate (full depl.; U.S. and 1 Gb/s only): $500 million/year

EEE savings - issues

- EEE includes LLDP Mechanism (Link Layer Discovery Protocol) that can enable longer latencies for increased savings beyond NIC
- Opportunities to coalesce packets to increase savings
- Does not cover cooling savings (e.g. data centers)
- Industry figures often DC (e.g. 3.3 V) so need to be inflated to account for AC/DC conversion losses
- Link speeds rising over time
- More IP-networked devices
- Some of these use Wi-Fi or MoCA, not Ethernet

General principles

- Much savings in networks only possible through technology standards
- Need “basic” research to identify opportunities
- Need to actively engage with standards orgs.
- Need public policy to signal interest in technology
  - So it is developed/deployed at all, and sooner
- Need to adapt test procedures and specifications
  - Consider savings in other devices
- Reward, then mandate new technologies
  - OK to require
- Track results to maintain process

Bonus topic: Energy reporting

- Concept
  - Each device in a building tracks its own energy status and reports to network in standard way
- Mechanism should be simple, extensible, universal
- Often requires no new hardware
- One protocol in development
  - Internet Engineering Task Force, Energy Management Working Group
    URL
- Policy should signal that energy reporting **will be required** and work towards good single standard protocol for this purpose

Summary

- Energy Efficient Ethernet a energy / network technology success story
- Many more do and will exist
  - Also need to consider technologies that increase energy use and how to respond
- Current policy structures not well suited to support more examples like it
- Network standby policy as good a place as any to drive this forward
- Energy reporting a good next topic to take up
  - But do several others also – possibly MoCA

Thank you