# Green Networking in the Next Generation Internet: Challenges and Issues

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ADCOM 2009, Bangalore, India, December 14, 2009

Slides and Audio/Video recordings of this talk are at:

http://www.cse.wustl.edu/~jain/talks/adcom09.htm

# Overview

1. Why Green Networking?
2. Why is the Current Internet not green?
3. What is being done to make it green?
   Recent Developments: Energy Efficient Ethernet , Proxy, EPA Energy Star
4. Further research problems

# Info and Comm Technology Energy Stats

- Aviation industry produces 2-3% of the green house gases
- Information and communication technology (**ICT**) equipment uses electricity that produces 2-3% of the green house gases.
- ICT emissions are doubling every 4 years
  $\Rightarrow$ fastest growing sector

# ICT Energy Stats (Cont)

Switch
250W × 1 year

Coal
1780 lbs

$CO_2e$
Two Tons

A switch produces 2 $tCO_2e/Yr$

**A tree consumes 3-15 lbs $CO_2$/yr**

$\Rightarrow$ 1300 Trees need to be planted to run a single switch

1300
Trees

# ICT Energy Stats (Cont)

One Small
Computer Server

=

One SUV with
15 miles/gallon

Ref: http://earth911.com/blog/2008/12/22/servers-suvs-15-mpg/

# ICT Energy Stats (Cont)

- Idle servers consume 50 to 80% of power at maximum load
- Energy is 2nd highest data center costs (10% rising to 50%)
- Cooling accounts for 20-50% of the total power consumption
- One PC left on 24x7 uses electricity emitting 1500 lbs of $CO_2$ per year

- Ref: An inefficient truth, http://www.globalactionplan.org.uk
- Ref: HTTP://UCLUE.OM/INDEX.PHP?XQ=724
- Ref: http://www.ee.unimelb.edu.au/people/rst/talks/files/Tucker_Green_Plenary.pdf
- Ref: http://www.nanog.org/mtg-0802/levy.html
- Ref: Http://esdc.pnl.gov/

# Whole Life View

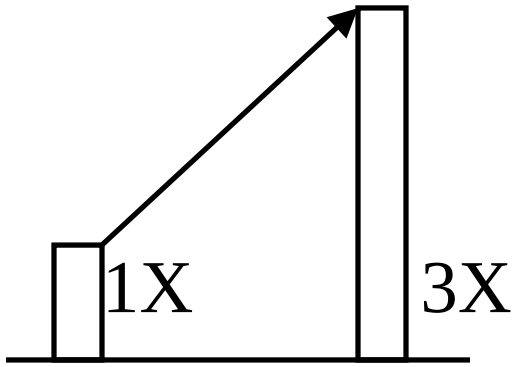
| Manufacturing | Use | End-of-Life |
|---|---|---|
| Toxins? | Idle Power? | Recycle? |

Ref: "Going Green True Tales from Gleaners Scavengers and Dumpster Divers" University of Oklahoma Press, 2009, ISBN 0806140135, 209 pp

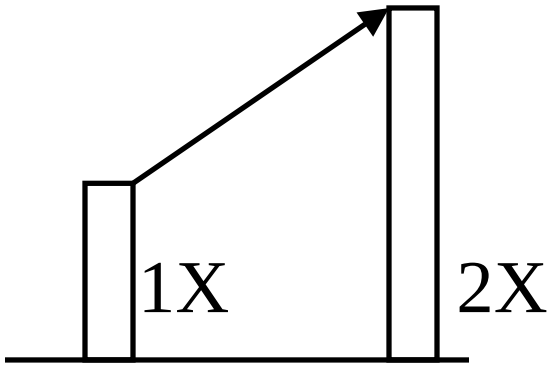
# Production vs. Operation

- Typical appliances (refrigerators, washer, dryer) have long life cycle
- IT appliances have short life cycle, high-energy manufacturing
- Short life ⇒ End-of-Life important ⇒ Recycle

Home Electrical Appliances

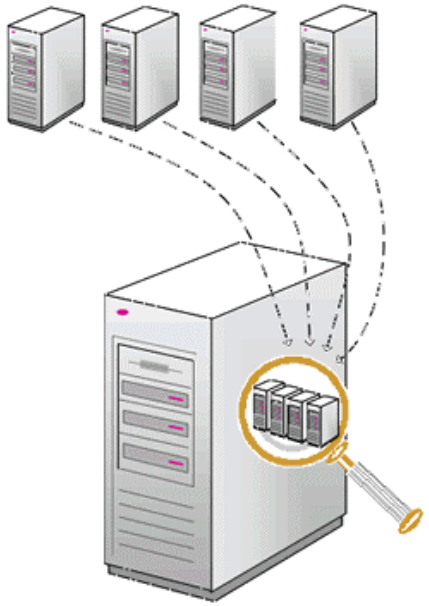



IT Equipment



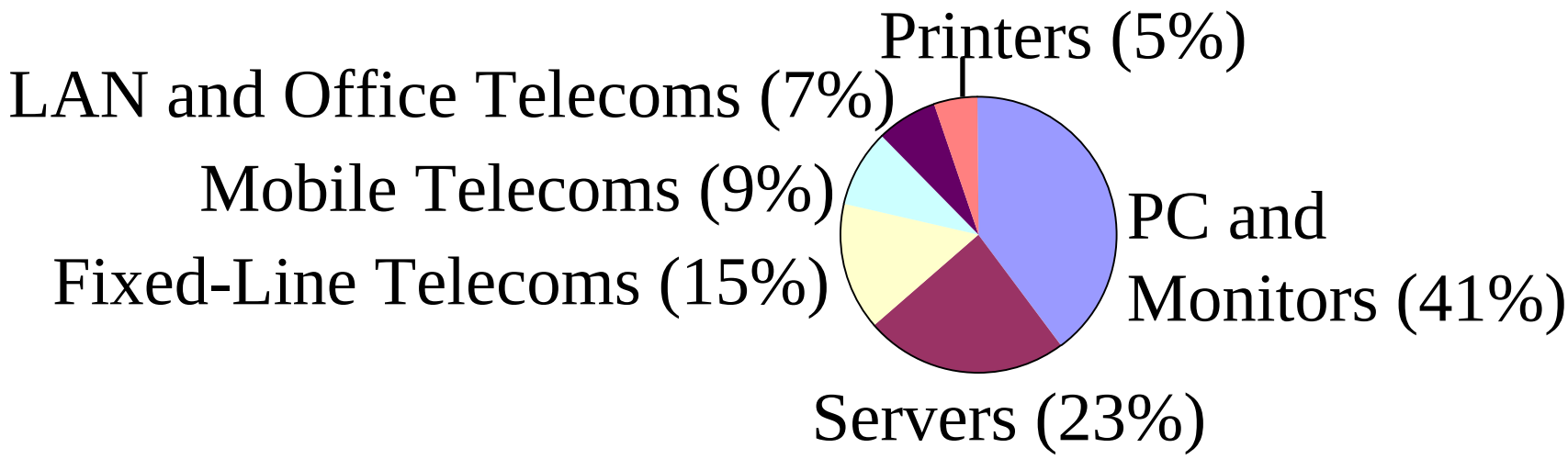
# Green Operation of Data Centers

- **Virtualize Servers**:
  Multiple servers on one hardware
  ⇒ Reduction in servers, floor space, cooling needs
- Locate data centers near sources of renewable energy (avoid 15% electric transmission losses)
- Cost of fiber optic cable is 5-10% of the cost of electricity transmission
- Move computing to cheap power (Follow the moon)



# Effect of Networking

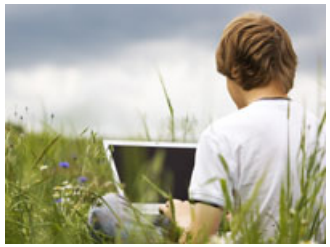
- PC's are the major power consumers
- Networking devices account for about 15% of a data center's total energy consumption




Ref: N. Chilamkurti, et al, "Green Networking for Major Components of Information Communication Technology Systems," 25th September 2009, EURASIP Journal of Wireless Communications and Networks

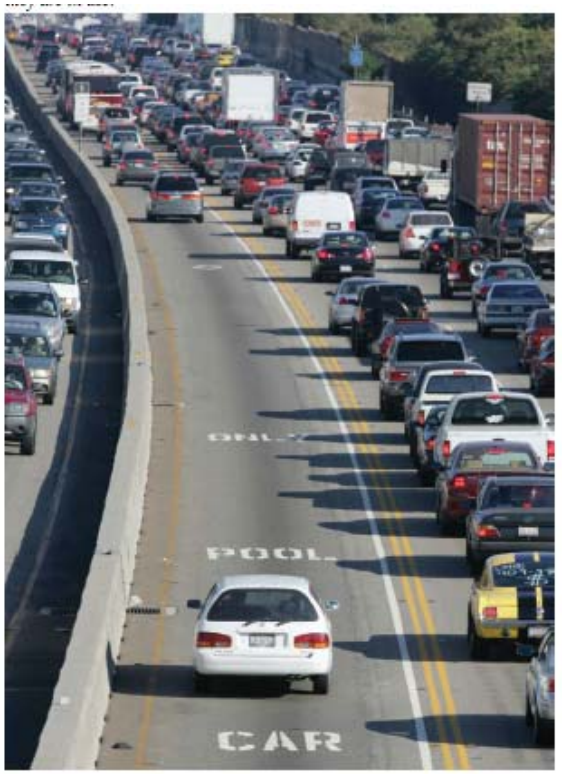
# Networks are Green Enabler

- Telecommuting:



- Video Conferencing

- Distance Learning




- ICT can help reduce 5 times its own footprint

# Network Component Design

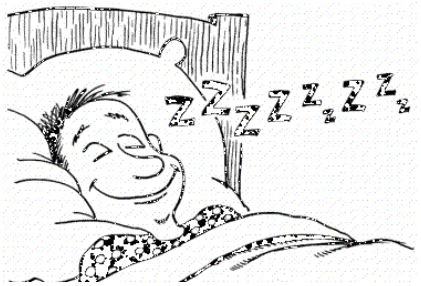
- Energy efficient components
- Efficient power adapters
- Eliminate fans or adjust based on needs
- Auto hibernate unused ports, devices
- Adjust signal strength based on cable length
- Challenge: Power over Ethernet
  - 15.4W/Port 384 port switch ⇒ 5.9kW
  - Increasing to 56W/Port ⇒ Larger battery backup
- Can save 2/3 by turning of VOIP phones 16 hours/day

# Future Internet Projects

- In 2005 US National Science Foundation started a large research and infrastructure program on next generation Internet
- Q: How would you design Internet today? Clean slate design.
- "Future Internet Design" (FIND): 48+ projects
- "Global Environment for Networking Innovations" (GENI): 29+ projects
- European Union: 7th Framework program
- Japan: AKARI (A small light in the dark pointing to the future)
- China, Korea, Australia, …20+ countries

# Problem with Current Internet

- Assumes live and awake end-systems
  Does not allow communication while sleeping.
  Many energy conscious systems today want to sleep.



- Ref: [JAI06]

# Always-on to Always-Available

| | Device | Always-On | Always-Available |
|---|---|---|---|
| | DSL | 1.5 W | 0.8 W |
|  | Residential Gateway | 11 W | 8 W |
|  | Media Server | 100 W | 10 W |
|  | Network Storage | 20 W | 2 W |
|  | Settop Box | 20 W | 10 W |
| | Applications | 120 W | 10 W |
| | **Total** | **272.5 W** | **40.8 W** |
| | | 100% | 15% |

Ref: Broadband Forum

# Network Performance and Sleep States

- Processors have multiple performance and sleep states
  - Performance states help when the processor is active
  - Sleep states help when the processor is inactive
- Dynamically set the forwarding capacity of a port based on load: 1 Gbps, 100 Mbps, 10 Mbps, disabled
- Network link utilization is low
  $\Rightarrow$ Disable ports, line cards, and switches when idle
- Ports are awakened when packets arrive
- A centralized power controller monitors the network and controls all ports
- Edge devices transmit packets in bursts

# Why Network Devices Cant Sleep?

- Broadcast packets: ARP. Continuous Hellos?
  1 to 3 packets per second
- DHCP leases expires
- Name resolution (NetBIOS)
- Management (SNMP and Pings)
- Broadcast traffic in office:

| ARP | NBNS | IPX | NBDGM | LLC | ANS | RPC | BOOTP | NTP | Other |
|---|---|---|---|---|---|---|---|---|---|
| 46% | 23% | 10% | 6% | 3% | 3% | 3% | 2% | 1% | 3% |

- Multicast traffic in office:

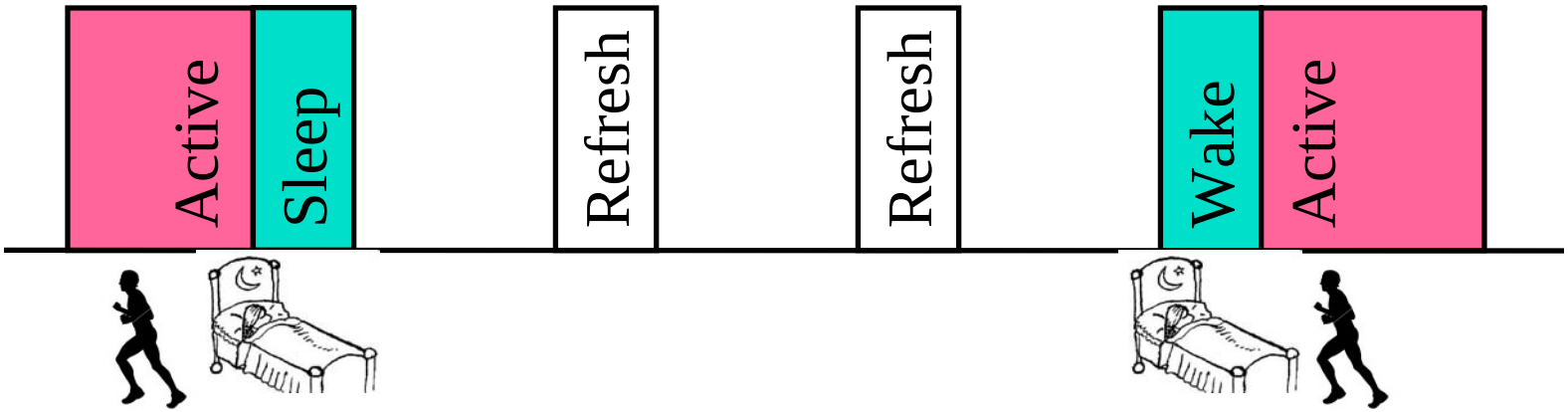
| HSRP | SSDP | PIM | IGMP | EIGRP | Other |
|---|---|---|---|---|---|
| 60% | 25% | 6% | 5% | 2% | 2% |

NBNS = Netbios Name Service
NBDGM = Netbios Datagram Service
HSRP=Hot-Standby Router Protocol
SSDP=Simple Service Discovery Protocol

Ref: S. Nedevschi, et al, "Skilled in the art of being idle: reducing energy waste in networked Systems," NSDI 2009.

# Energy Efficient Ethernet

- IEEE 802.3az. To finish Sept 2010..
- LAN utilization is low, typically 1% ⇒ 90% savings
- **Low Power Idle**: 1 us wake up
  - During idle period, NICs sleep
  - Wake up periodically to check

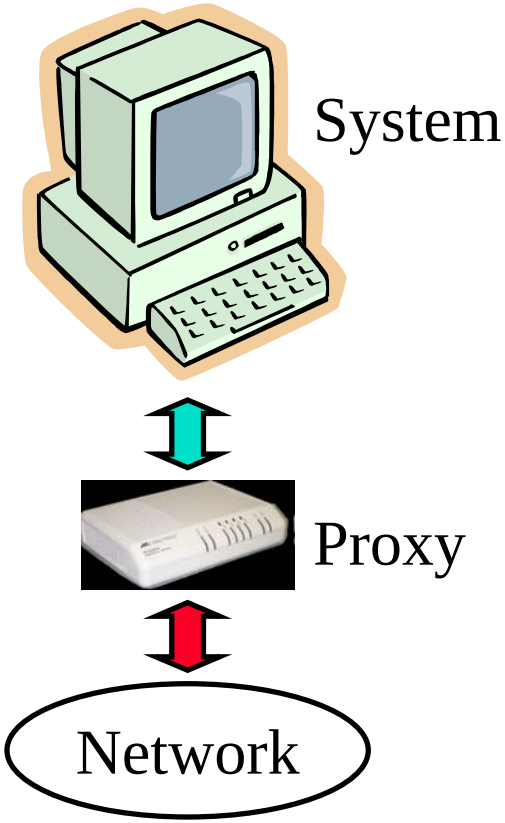


# Energy Efficient Ethernet (Cont)

- Infineon announced gigabit EEE in August 2009
- Next: ADSL Low power mode

# ECMA TC32-TG21 Proxy Support

- Host transfers its network state to proxy and goes to sleep
- Proxy responds to routine traffic (ARP, DHCP, TCP, ICMP, SNMP, SIP, …)
- Wakes up the host if needed
- Proxy can be in host NIC or separate box
- ECMA TC32-TG21 standard on "Proxy support for Sleep Modes," March 2010



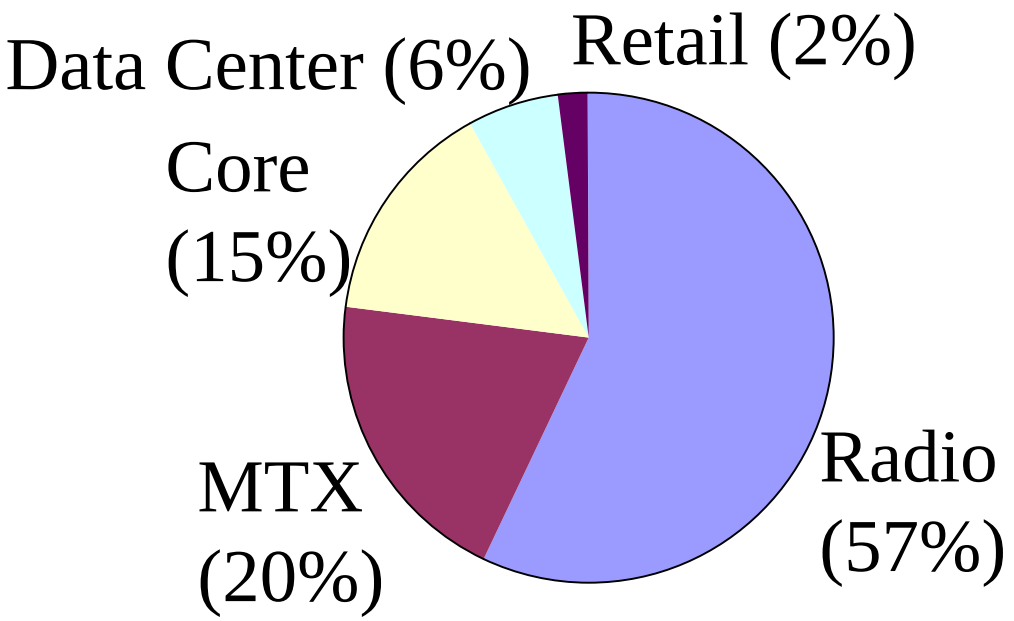
# EPA Energy Star


- Started in 1992 by US EPA
- Has been adopted by EU
- Covers many appliances
- Includes PCs, Laptops,
- V5.0 adopted in June 2009
- V5.0 includes **proxy** support
- Work started to include servers: Tier 1 released for comments. Tier 2 started in September 2009
- Tier 2 will include **EEE**

Ref: EPA, "ENERGY STAR Program Requirements for Computers, Version 5.0, 2009.

# Wireless Telecommunications

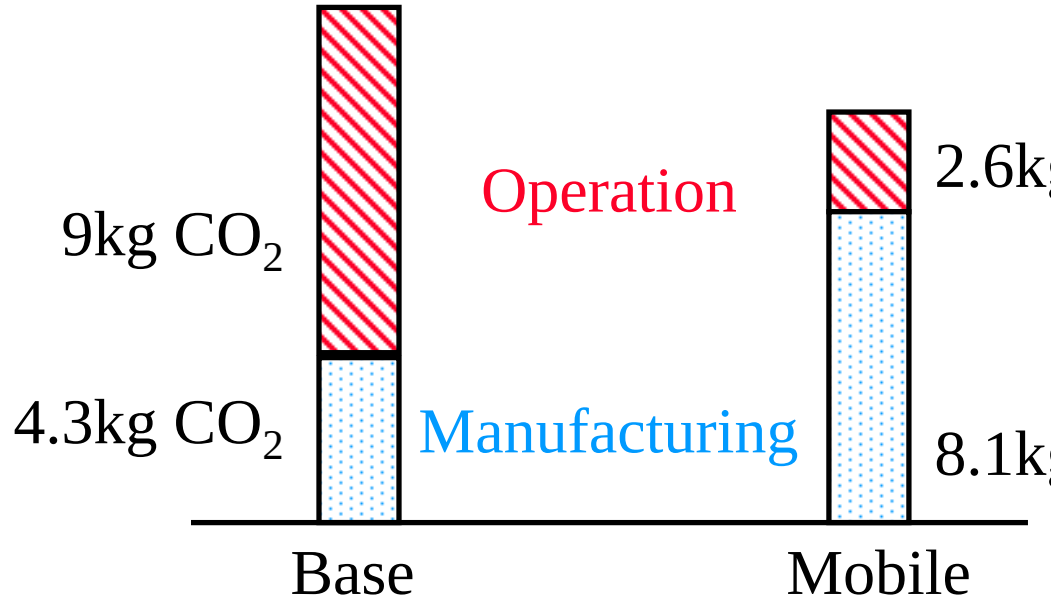
- 57% of the operator's electricity use is in radio access




Ref: Tomas Edler, "Green Base Stations – How to Minimize $CO_2$ Emission in Operator Networks," Ericsson, Bath Base Station Conference 2008

# Wireless Telecommunications (Cont)

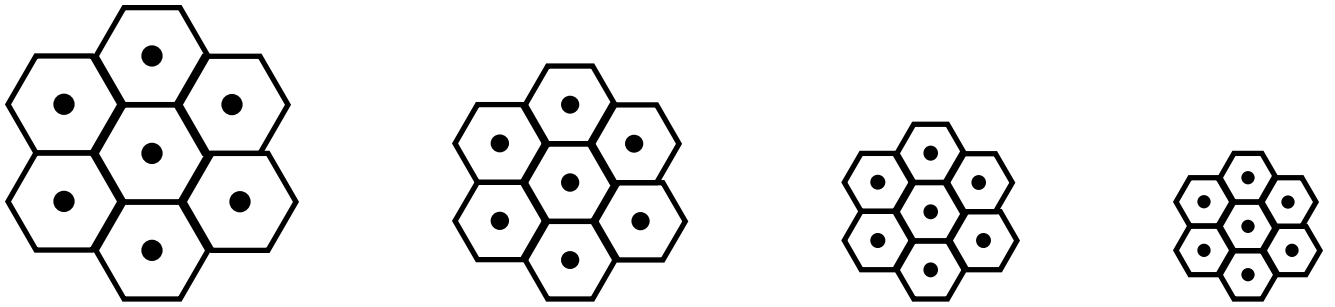
- Base stations use most of the energy during operation
- Subscriber devices use most of the energy in manufacturing




Ref: Tomas Edler, "Green Base Stations – How to Minimize $CO_2$ Emission in Operator Networks," Ericsson, Bath Base Station Conference 2008

# Wireless Telecommunications (Cont)

- Power consumption is a major issue in emerging markets
- Use renewable energy at base station
- Sleep techniques to allow power to scale with load
- Macro vs. Micro vs. Pico vs. Femto cells
  Energy is proportional to distance
  ⇒ operating vs. manufacturing energy tradeoff



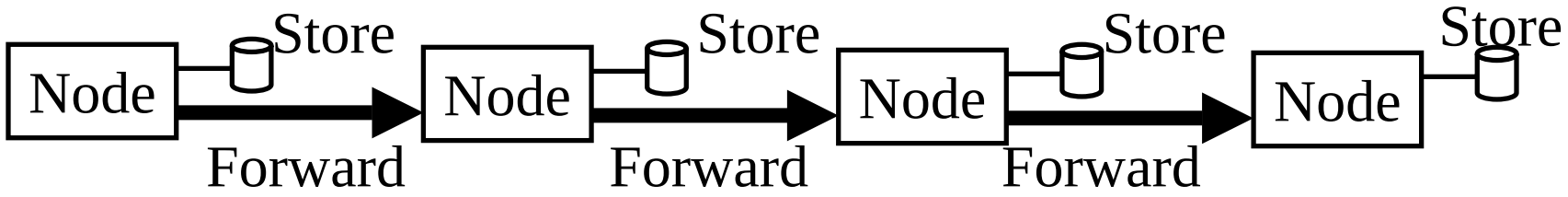
# Research Topics

- Energy aware network (H/W+Topology) design
- Energy aware protocol design
- Traffic shaping for energy saving
  $\Rightarrow$ Allowing nodes to sleep more
- Traffic engineering for energy saving
  $\Rightarrow$ Routing to allow major portions of network to sleep
- Energy efficient discovery of sleeping devices
- Energy efficient P2P, Webcams, and Sensors
- Data caching for energy saving
  $\Rightarrow$ Reduce traffic on the network

Ref: Ken Chriestensen, Keynote, LCN 2009

# Delay/Disruption Tolerant Net (DTN)

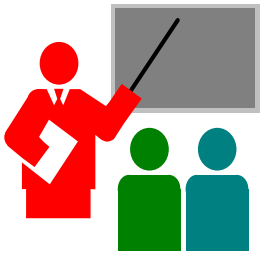
- Intermittent Connectivity.
- Scheduled disconnections (Daily power cuts)
- Long or variable delay
- Asymmetric data rates
- High Error Rates



# Top 10 Features of Next Generation Internet

1. Security
2. Mobility
3. Disruption Tolerant
4. Green: Proxy, Sleep Modes,
5. Services: Storage, Translation, Monitoring
6. User/Data-Centric: Network support of data objects
7. Easy to use: Self-organizing, better user control
8. Organizational Representation
9. Virtualizable to create Application Specific Context
10. Policy Enforcement

# Summary



1. Internet is a green-enabler.
2. Current networking protocols are energy-unaware. Networking/Networked equipment can't sleep.
3. Green architecture will save energy not only in networking but even more in networked equipment.
4. IEEE, IETF, ITU, ECMA, and numerous industry groups working on green networking
5. Green networking is an important aspect of Future Internet.

# References

- References on Green Networking, http://www.cse.wustl.edu/~jain/refs/gnet_ref.htm