Energy Consumption in IP Networks

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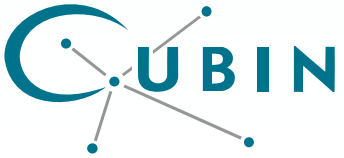
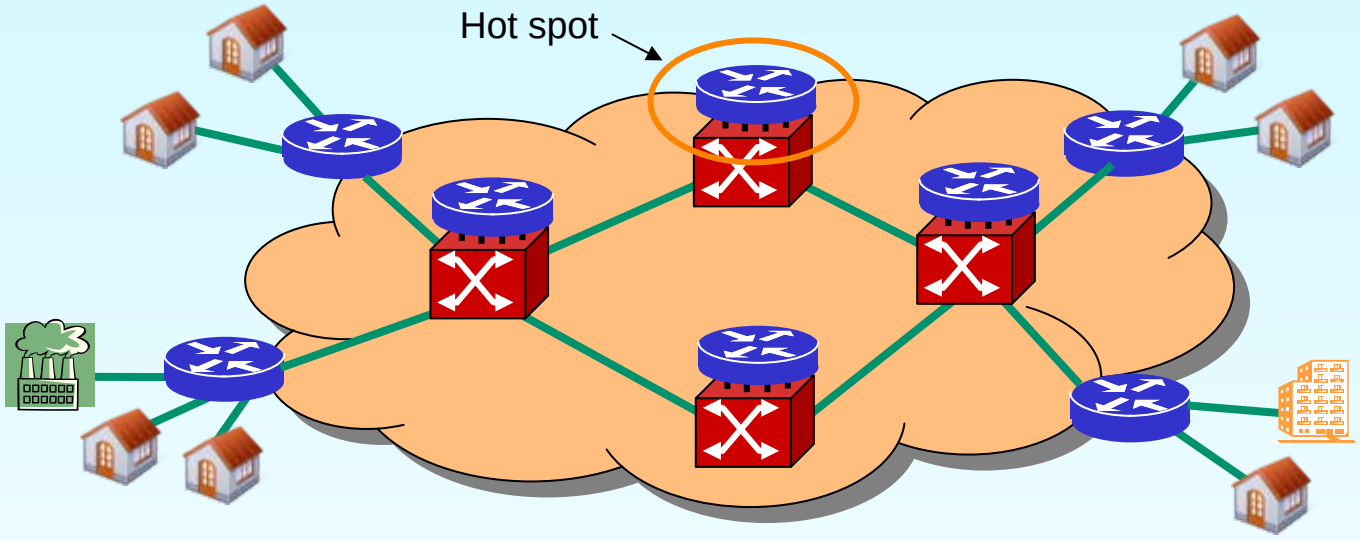
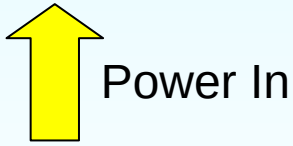


Energy Consumption of the Network



Why should we be interested in energy?

- OPEX
- Greenhouse Impact
- Managing “Hot Spots”
  - Getting the energy in
  - Getting the heat out
- Energy-limited capacity bottlenecks
- Enabling energy efficiencies in other sectors



Where are We Heading ?

- More users
- More data-intensive applications, e.g. video
- More often and for longer periods
- Increasing demand ⟶ operators provide faster access and increased core capacity
- New applications enabled by faster access

Energy Consumption Grows

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Summary

- Modeling energy consumption of the Internet
  - Core, metro, and access networks
- Energy in network routers
- Energy in optical transmission
- Will (can) optical switching technologies help to reduce energy consumption?

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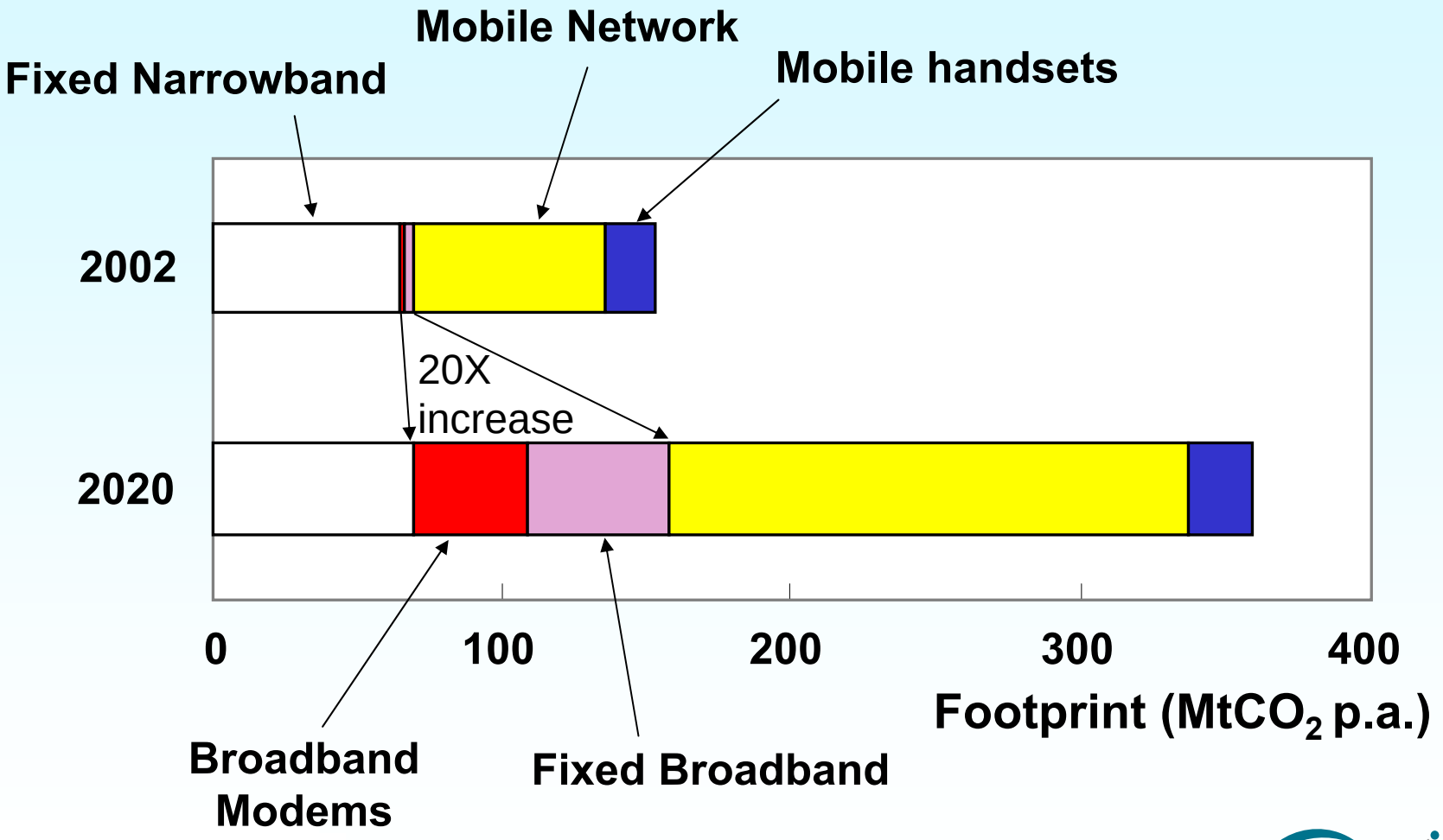
What is the Carbon Footprint of Telecoms?

Global Telecoms Footprint (devices & infrastructure)



Adapted from "SMART 2020: Enabling the low carbon economy in the information age," *GeSI, 2008* www.gesi.org

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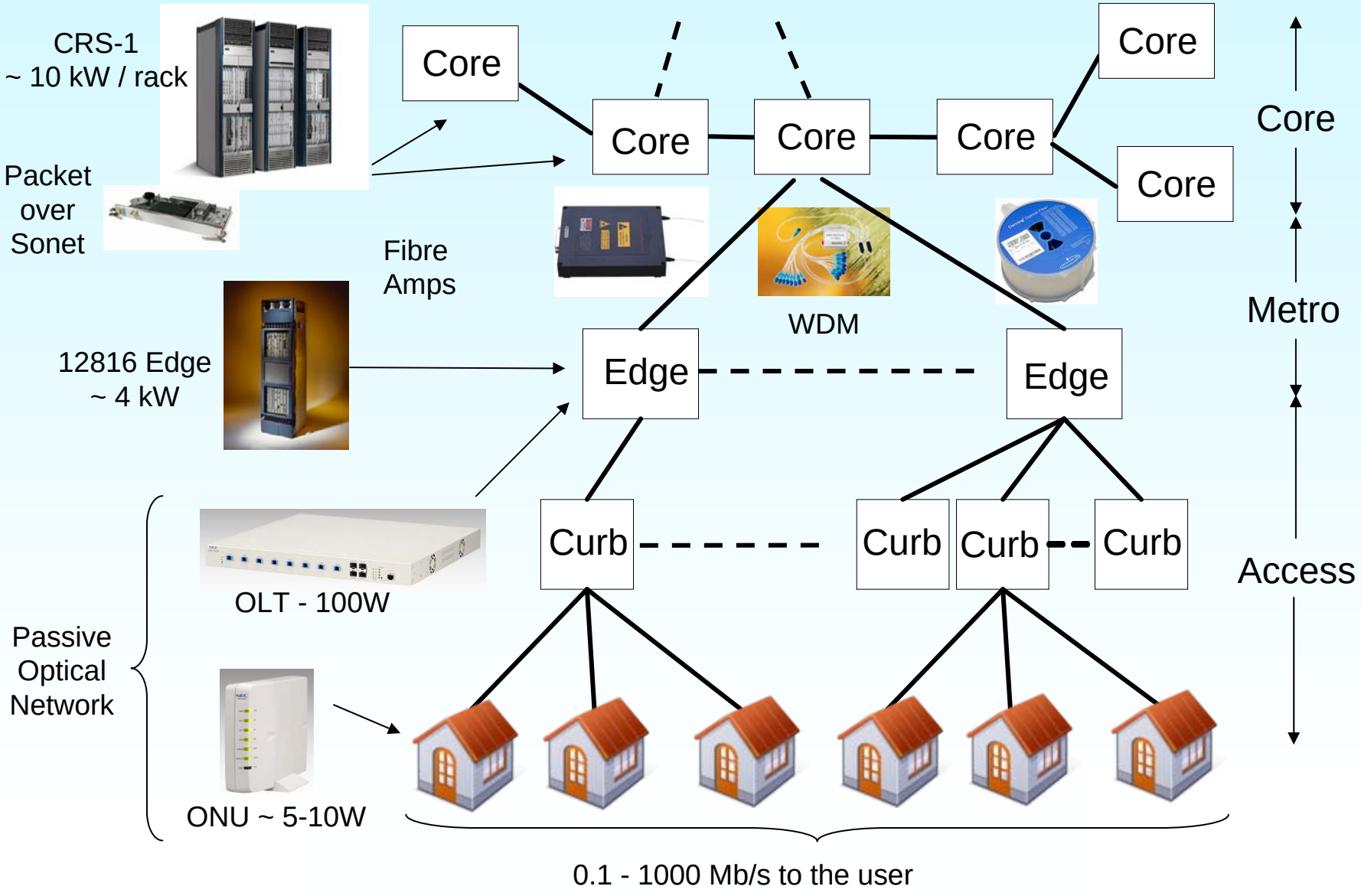
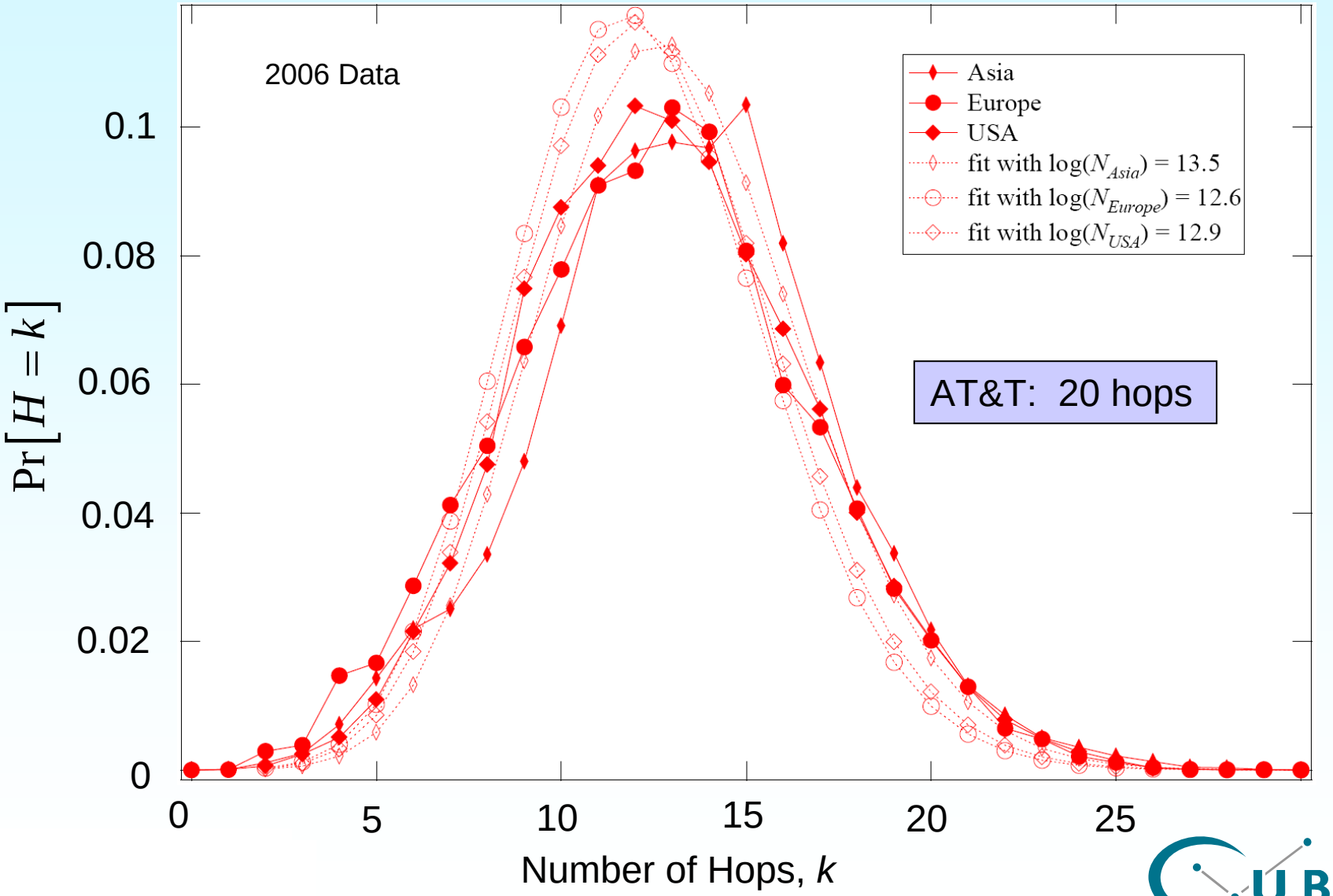
Energy Model of Simple IP Network



Baliga et al., 2007

Number of Hops in the Internet



Source: P. Van Mieghem,
"Performance Analysis of Computer Systems and Networks", Cambridge (2006)

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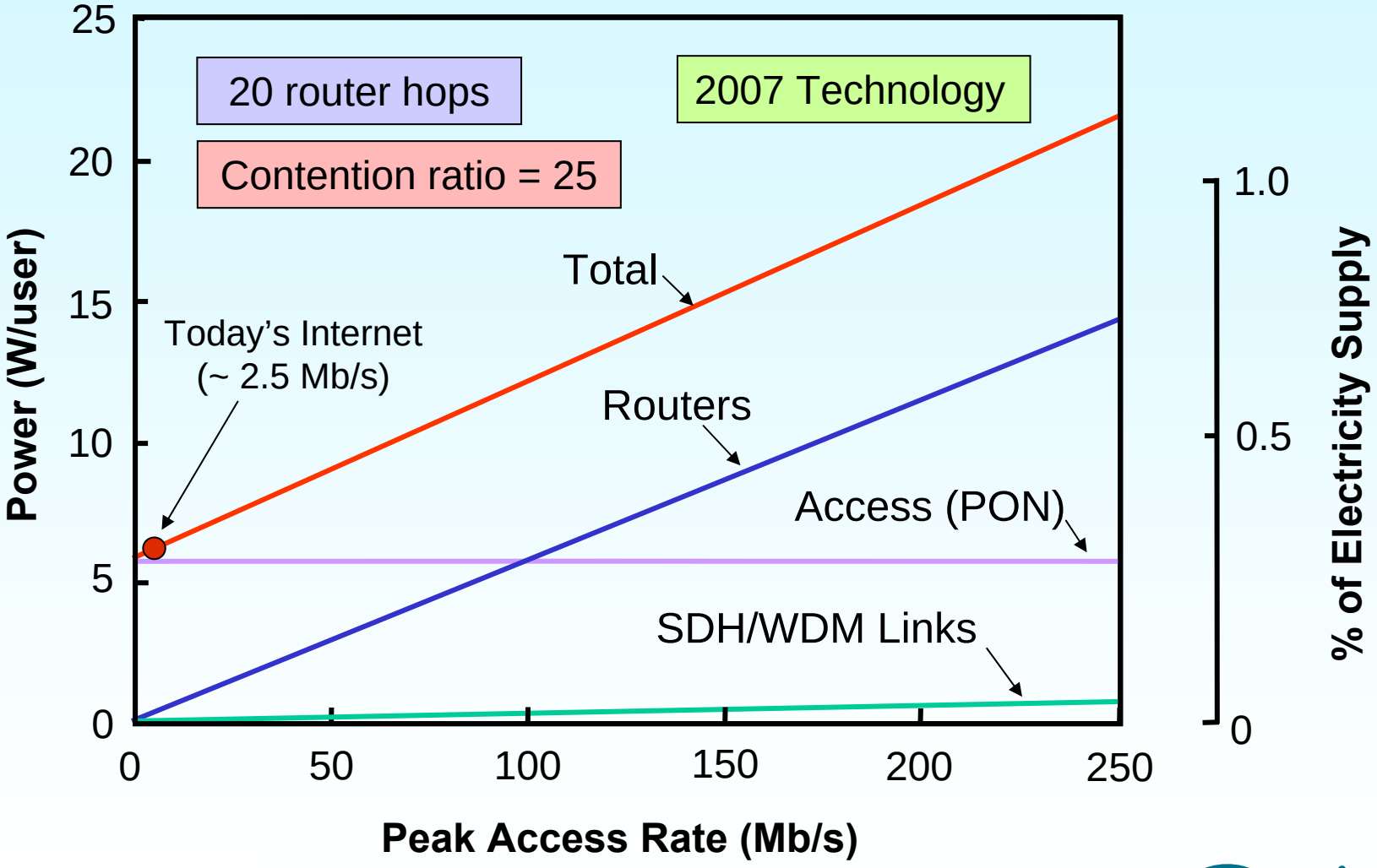
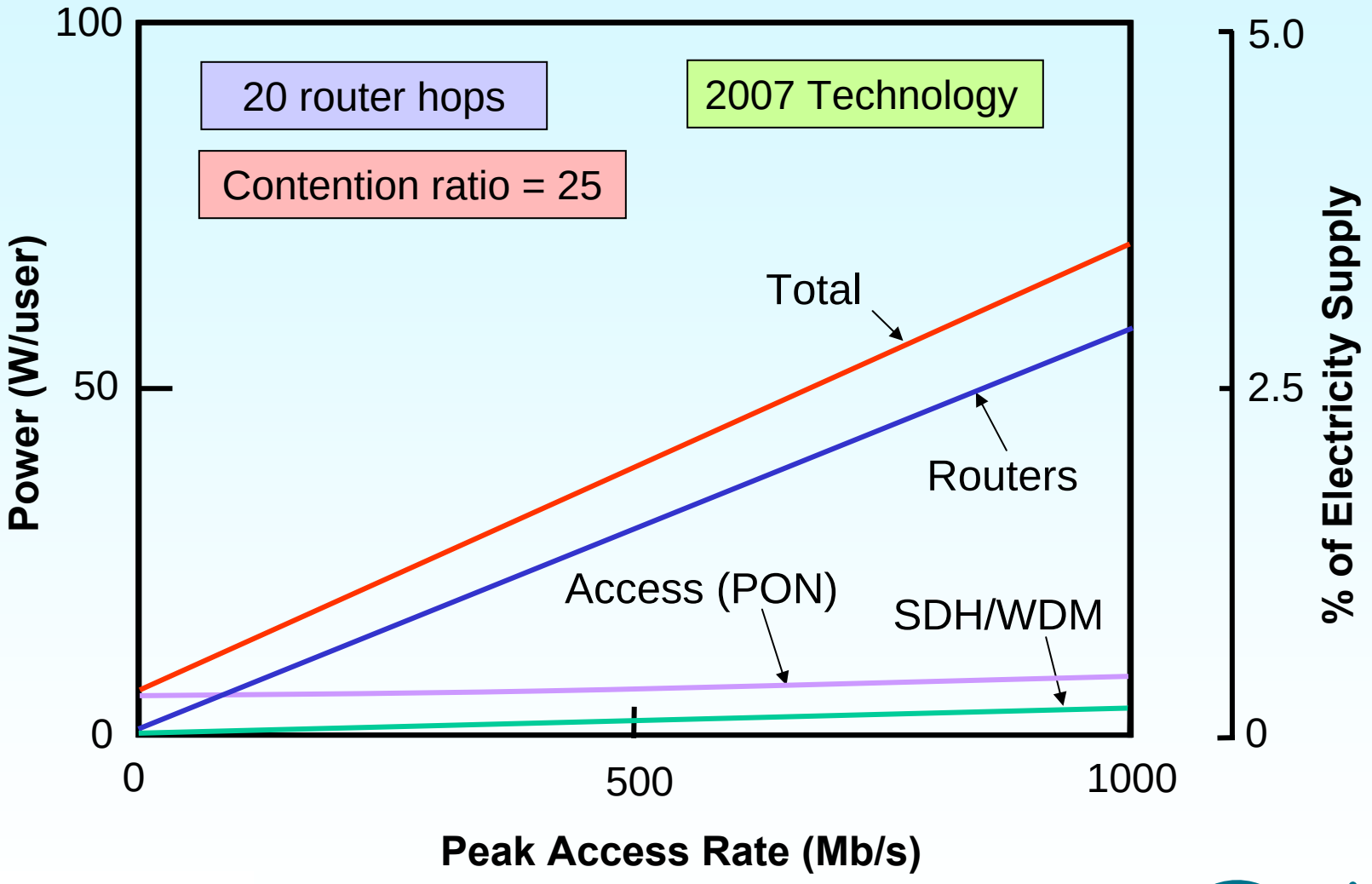
Power Consumption of IP Network



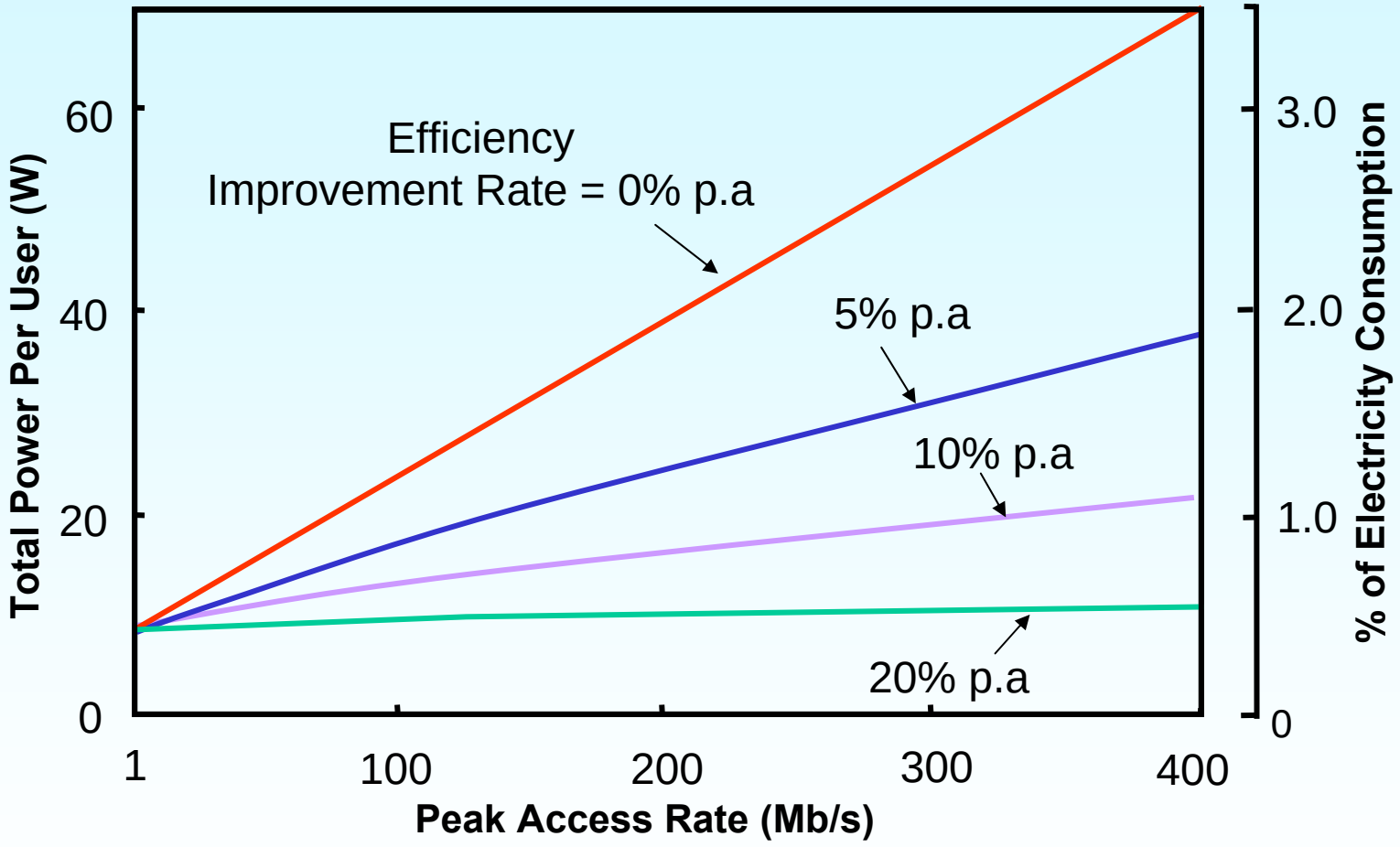
Baliga et al., 2007

Ultra-Broadband Access



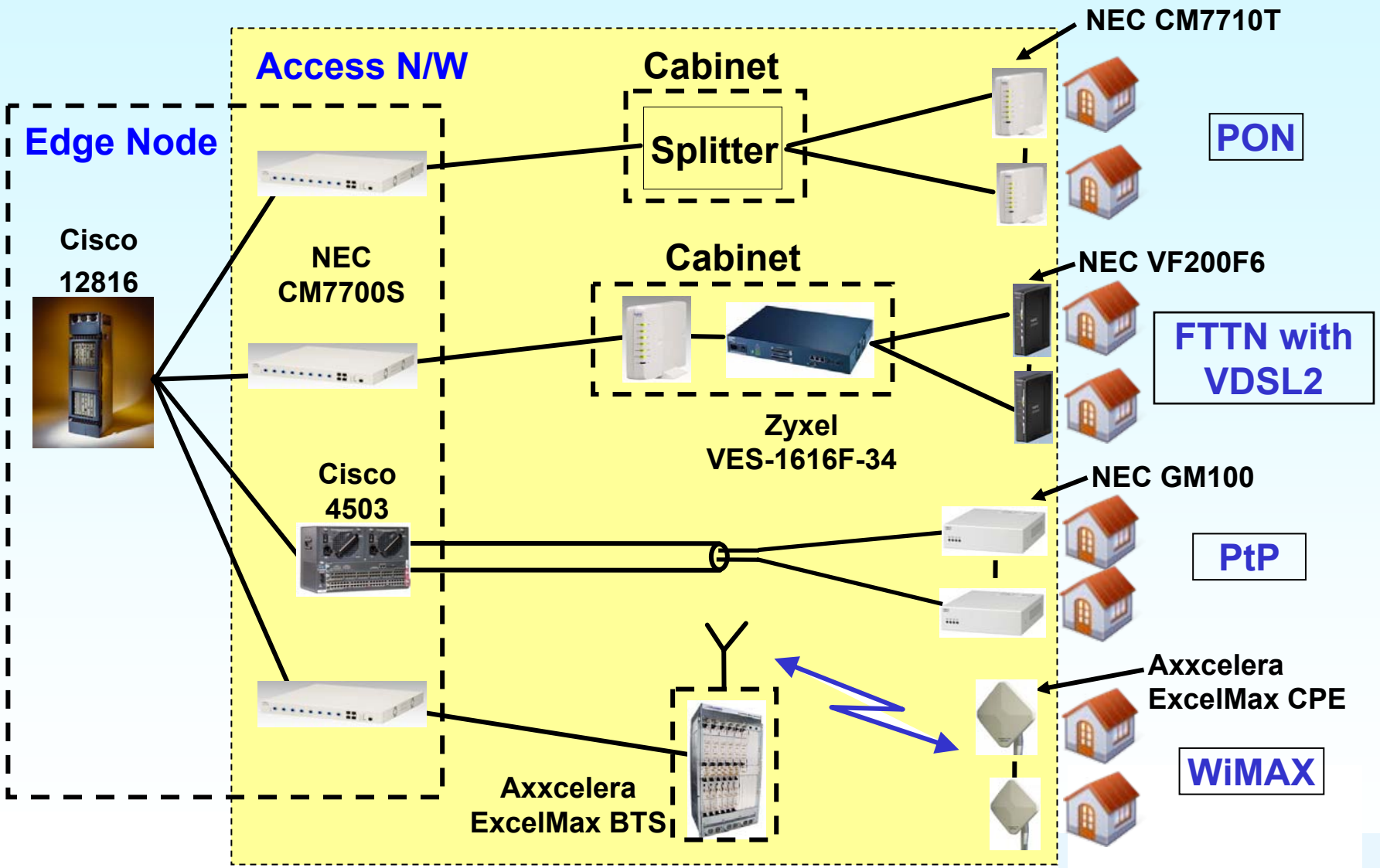
Baliga et al., 2007

Technology Improvements

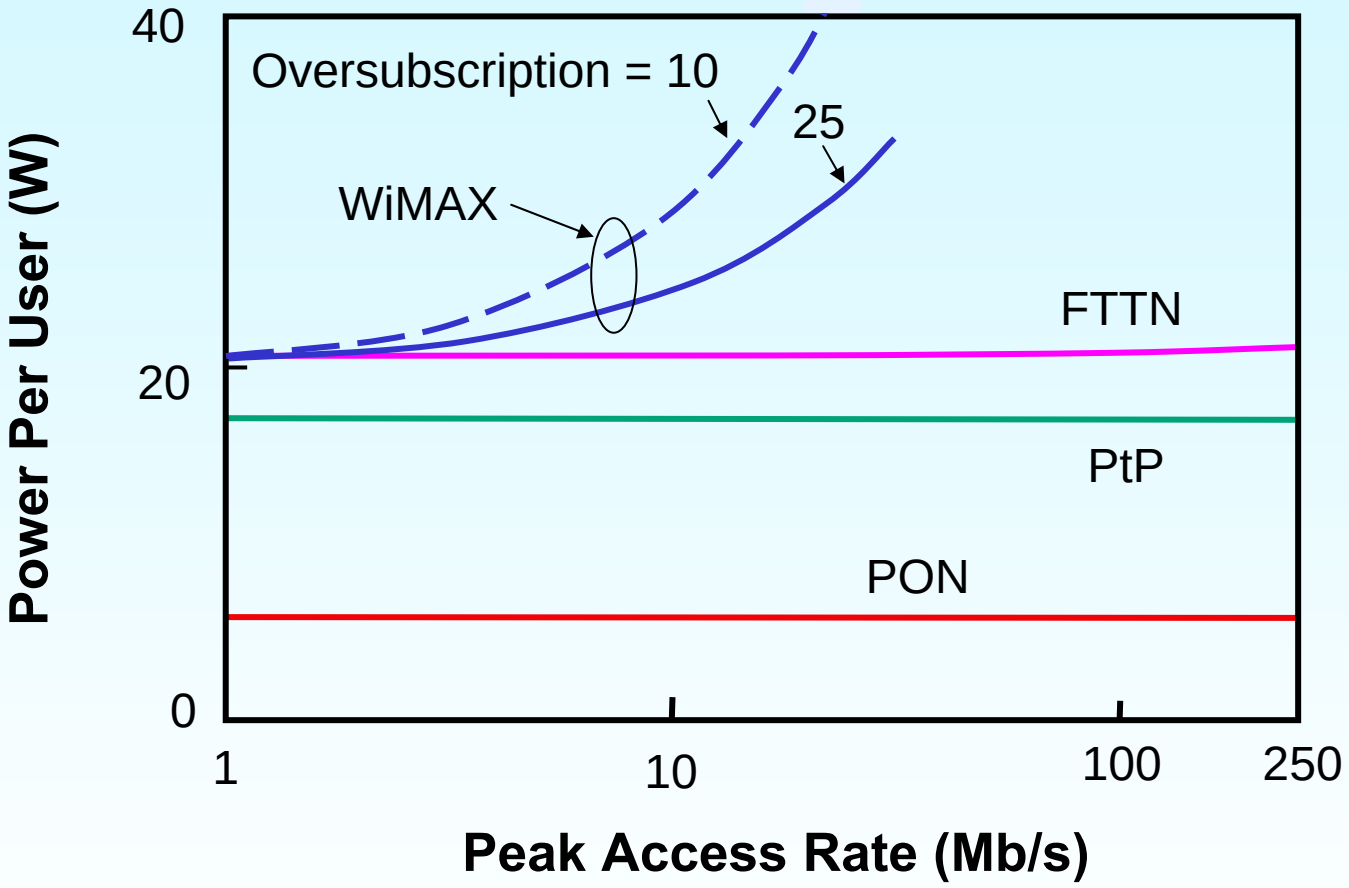


Baliga, et al, 2008, unpublished

Energy Consumption in Access Networks



Power Consumption in Access Networks



- Wireless access consumes more energy than optical access
- PON FTTH is “greener” than FTTN

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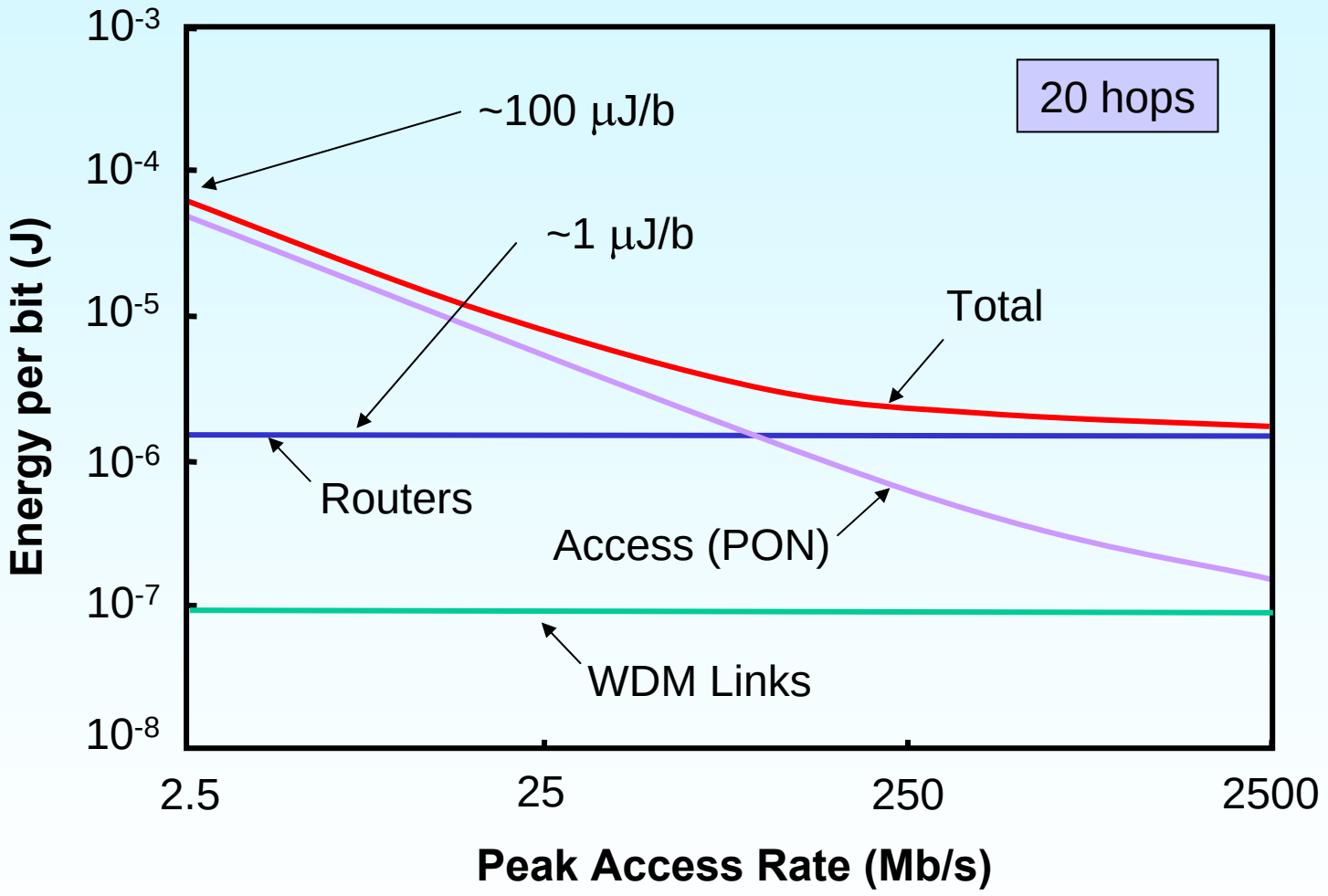
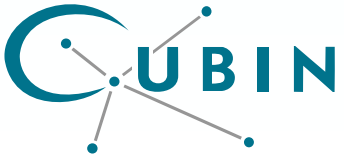
Network *Energy* Consumption per Bit

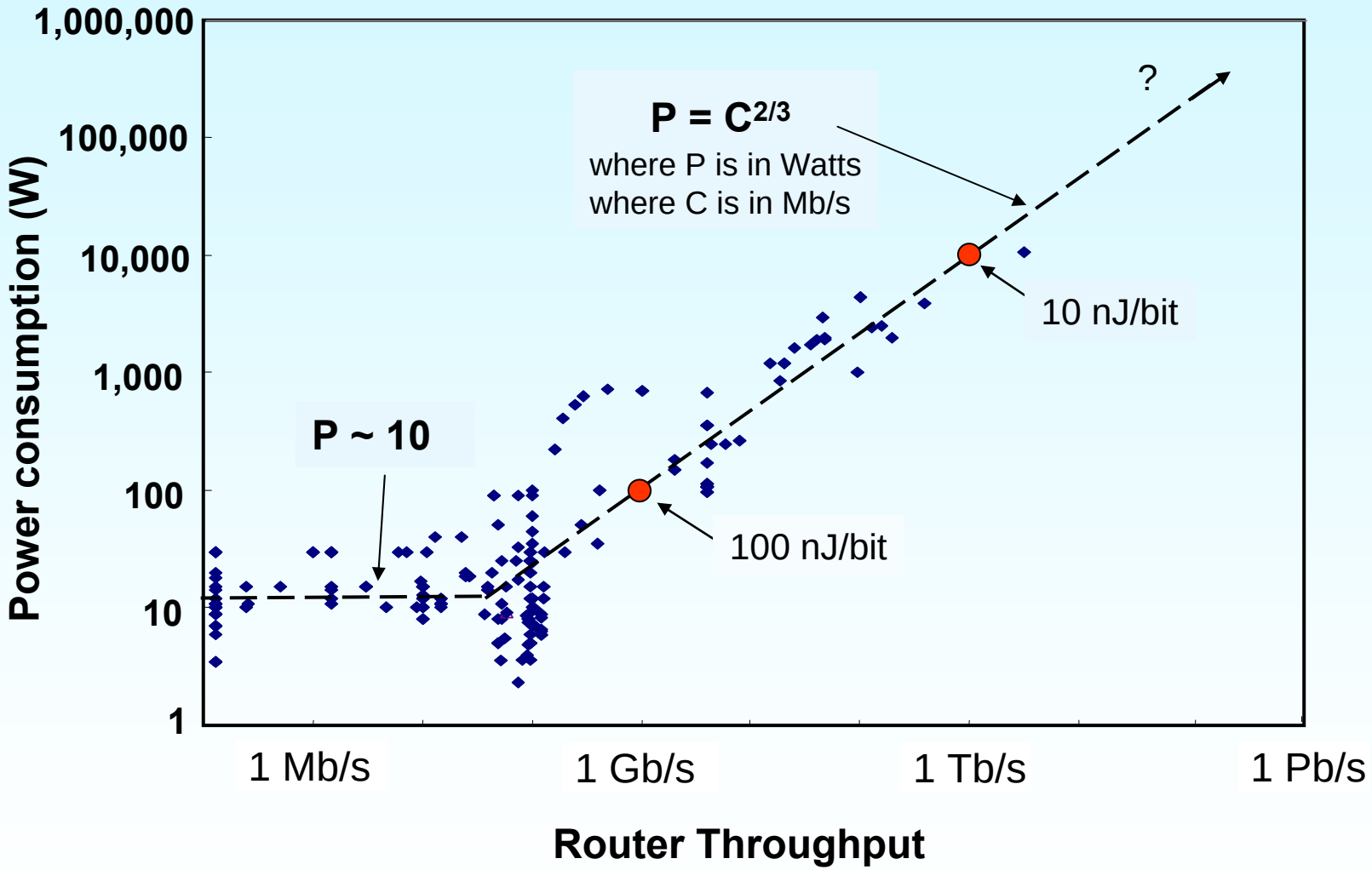


Observations

- Optical transport (WDM) consumes relatively little energy
  - < 5% of energy
  - > 25% of CAPEX
- Access network dominates at low rates
  - Standby/Sleep mode needed
- Network routers dominate at higher rates
  - Need to
    - **reduce hop count**
    - **improve router efficiency**
    - **manage distribution and replication of content (IPTV)**



Power Consumption in Routers



Source: METI, 2006, Nordman, 2007

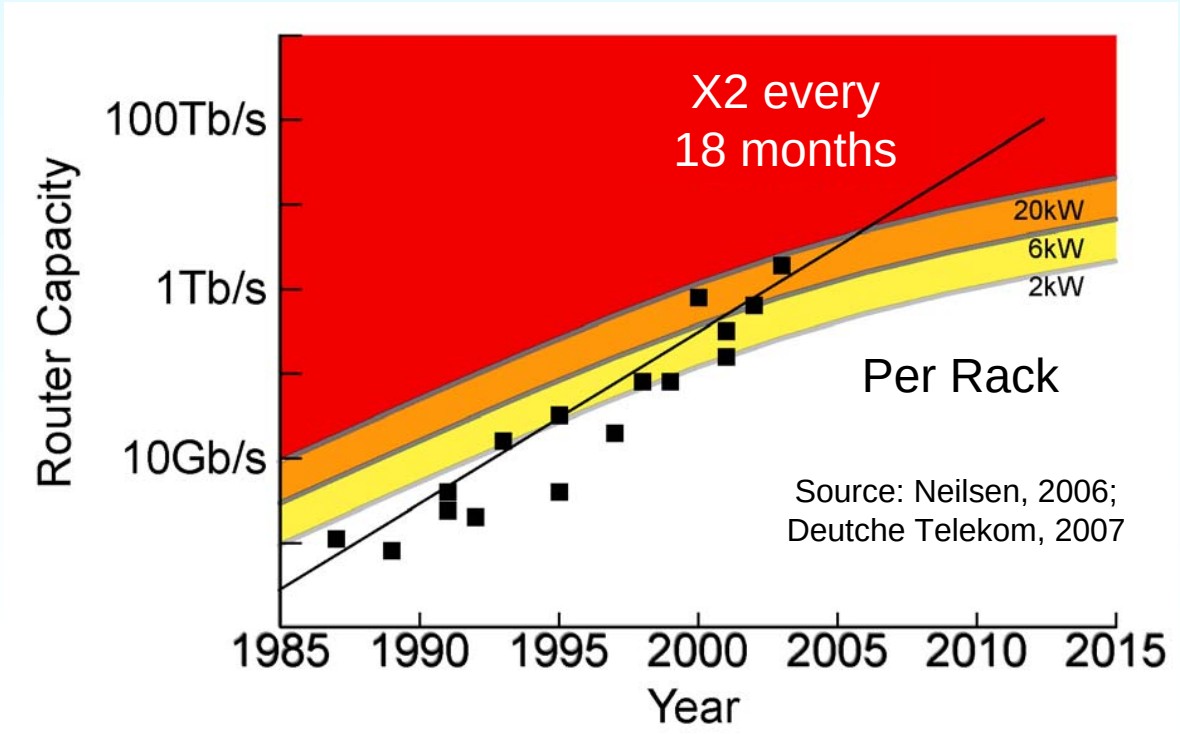
Energy Bottleneck

High-end router: Cisco CRS-1

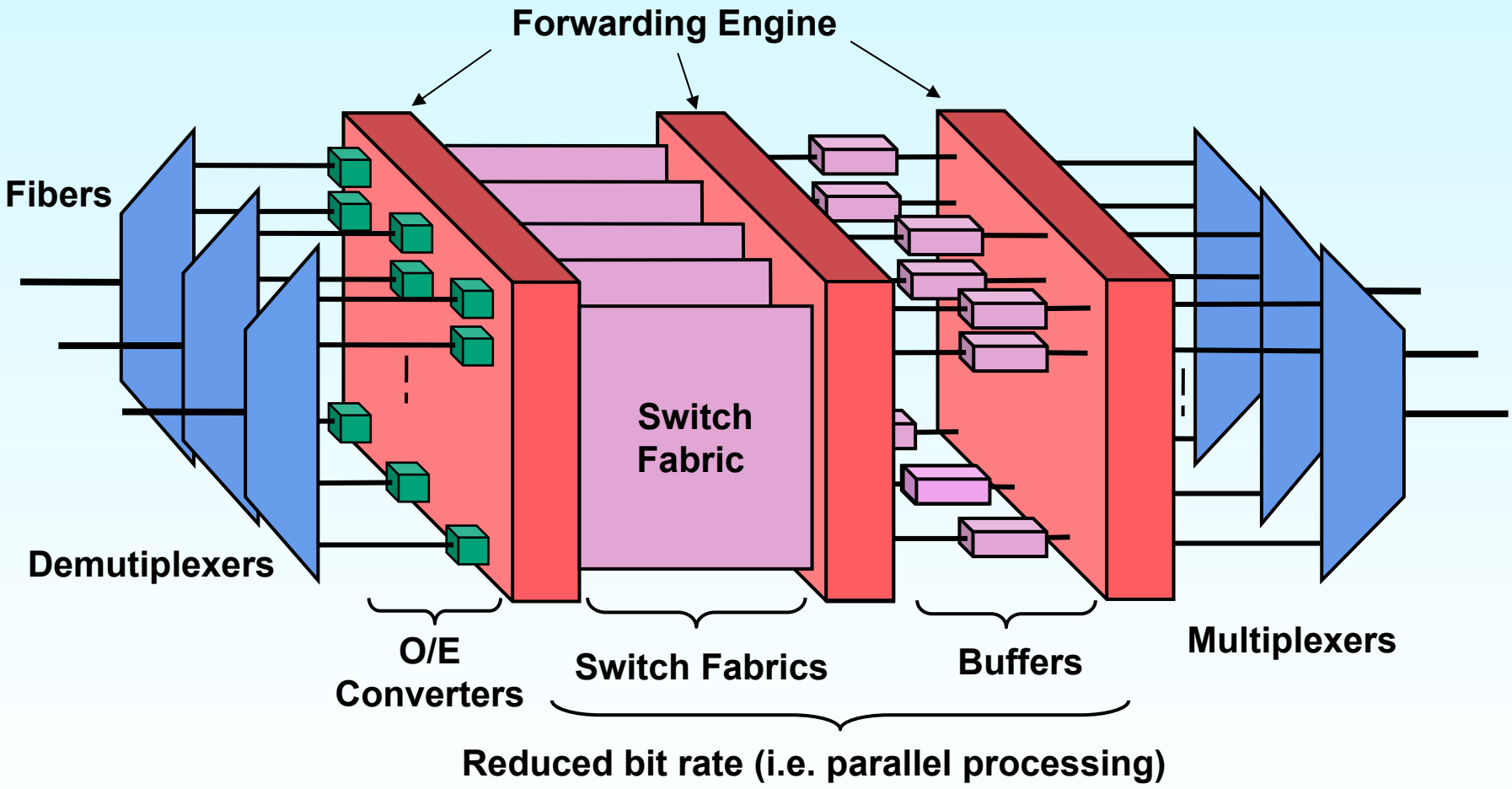
Linecard Chassis
Capacity: 0.64 Tb/s
Power: 13.6 kW

Switch Fabric Chassis:
Power: 8 kW

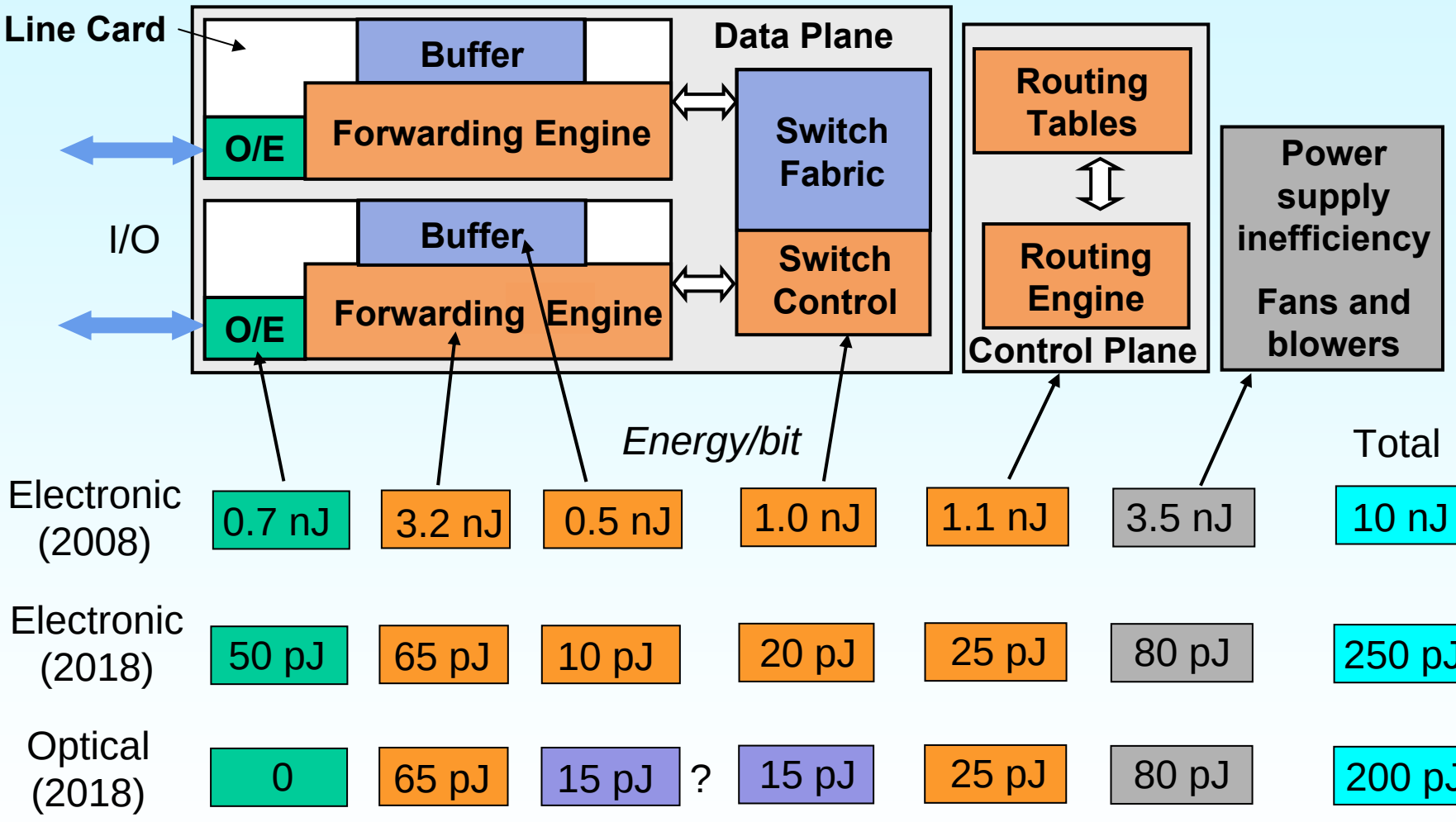
Fully equipped:
Multi-rack router
Capacity: 41 Tb/s
Power ~ 1 MW



Electronic Routers



Energy in Electronic and Optical Routers



Optical Packet Switching is not a promising alternative

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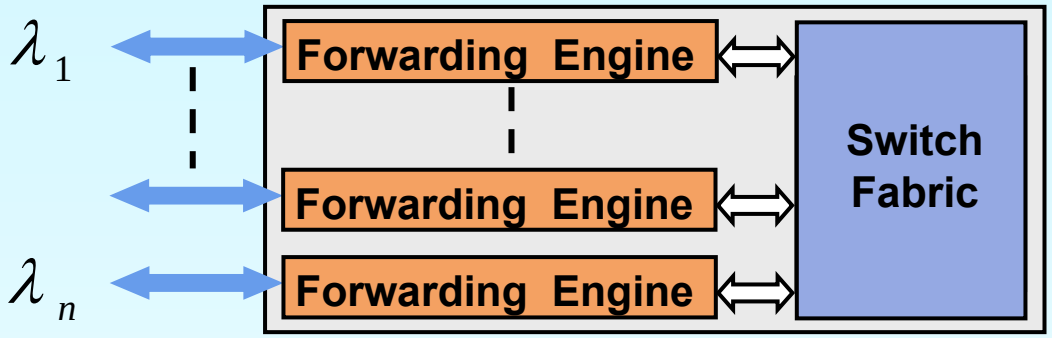
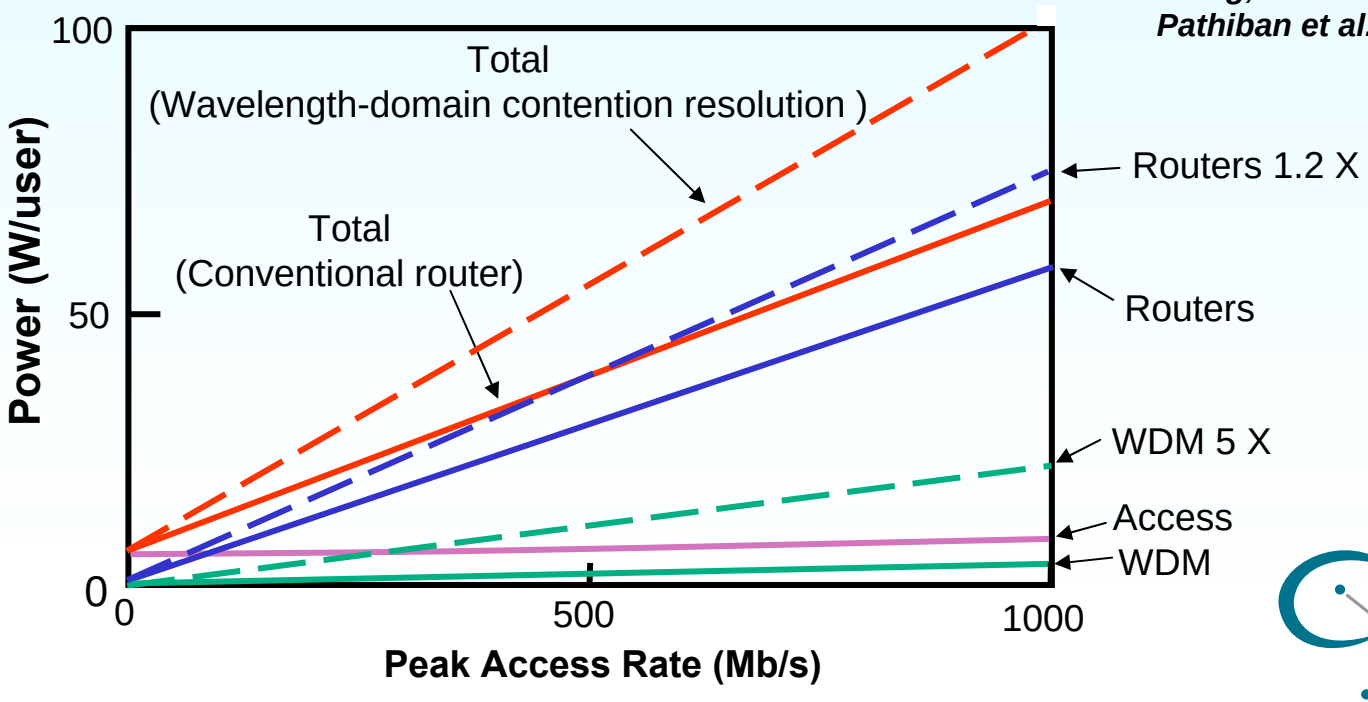
G. Epps, Cisco, 2007, ITRS, 2005, R. Tucker, JLT, 2006

Contention Resolution in the Wavelength Domain



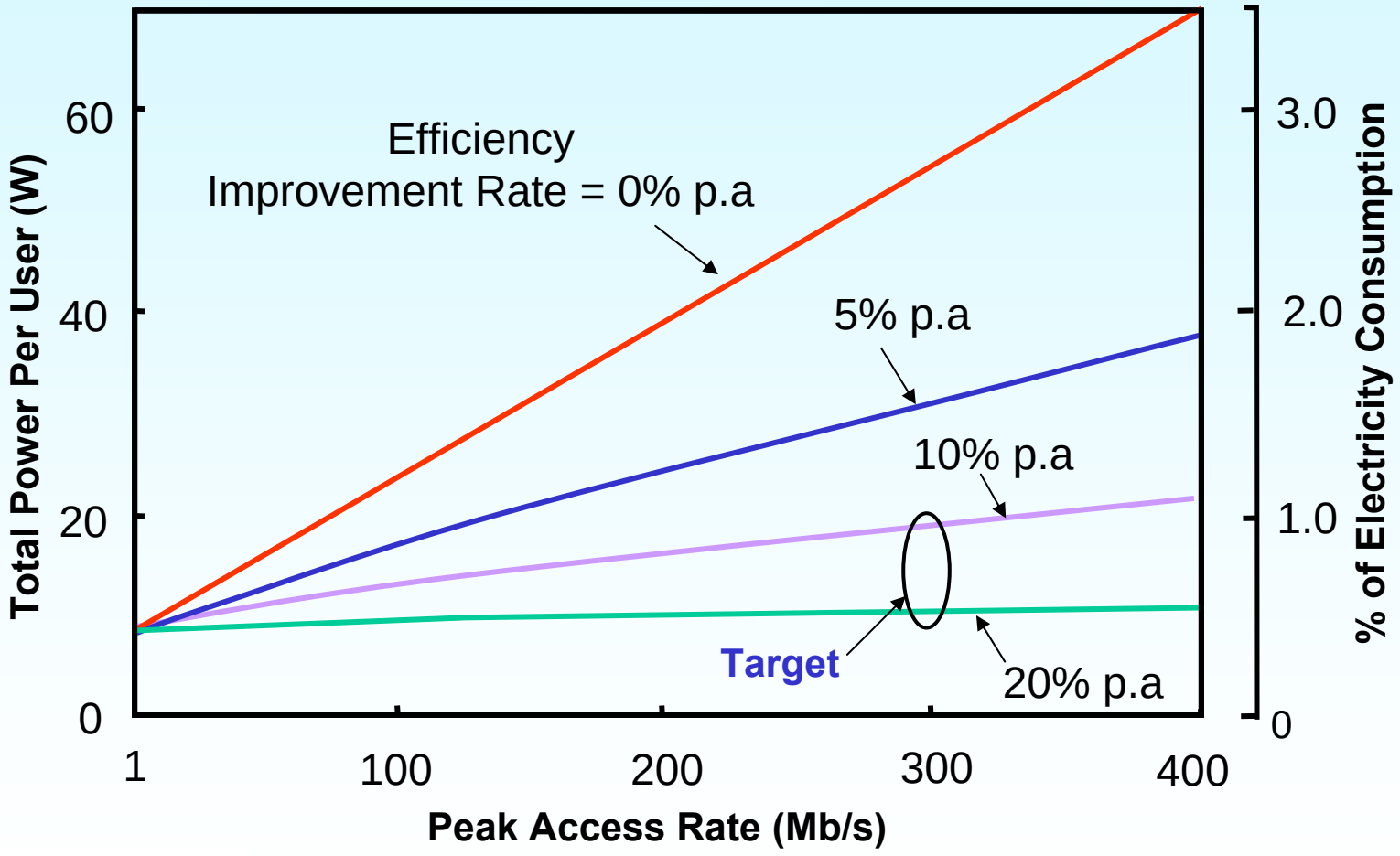
Fatal Flaw: **Require large n** for low blocking probability (n ~3 -10 x)

Wong, JLT 2006
Pathiban et al., JLT 2009



The Challenge

10 % - 20 % p.a. continuous improvement in efficiency



Baliga, et al, 2008, unpublished

Summary

- Energy consumption currently dominated by the access network
- The energy bottleneck in routers is looming
  - More significant than the so-called “electronic speed bottleneck”
- Key strategies for efficient network design
  - Control energy in the access network (e.g. sleep mode in modems)
  - Reduce the hop count (i.e. “agile” optical bypass)
  - Caching and content distribution networks
  - Continuous improvement in router efficiency