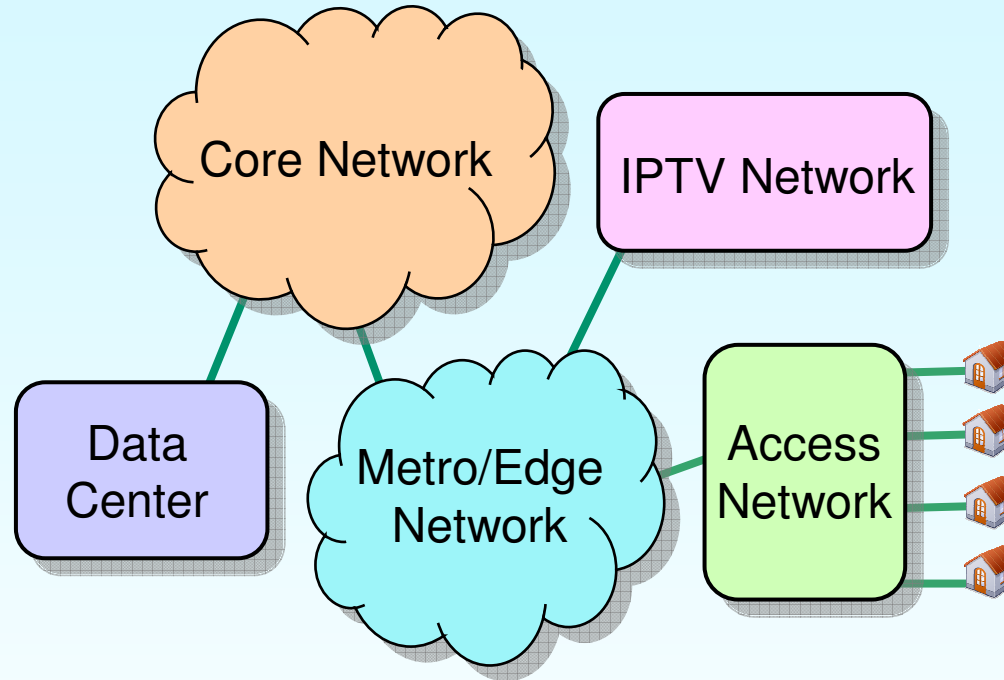# Energy Consumption of the Internet

Jayant Baliga

Robert W. Ayre, Kerry Hinton, Wayne V. Sorin, Rodney S. Tucker

**ARC Special Research Centre for Ultra-Broadband Information Networks
University of Melbourne**

**NATIONAL ICT AUSTRALIA** LIMITED

UBIN

# Energy and the Internet
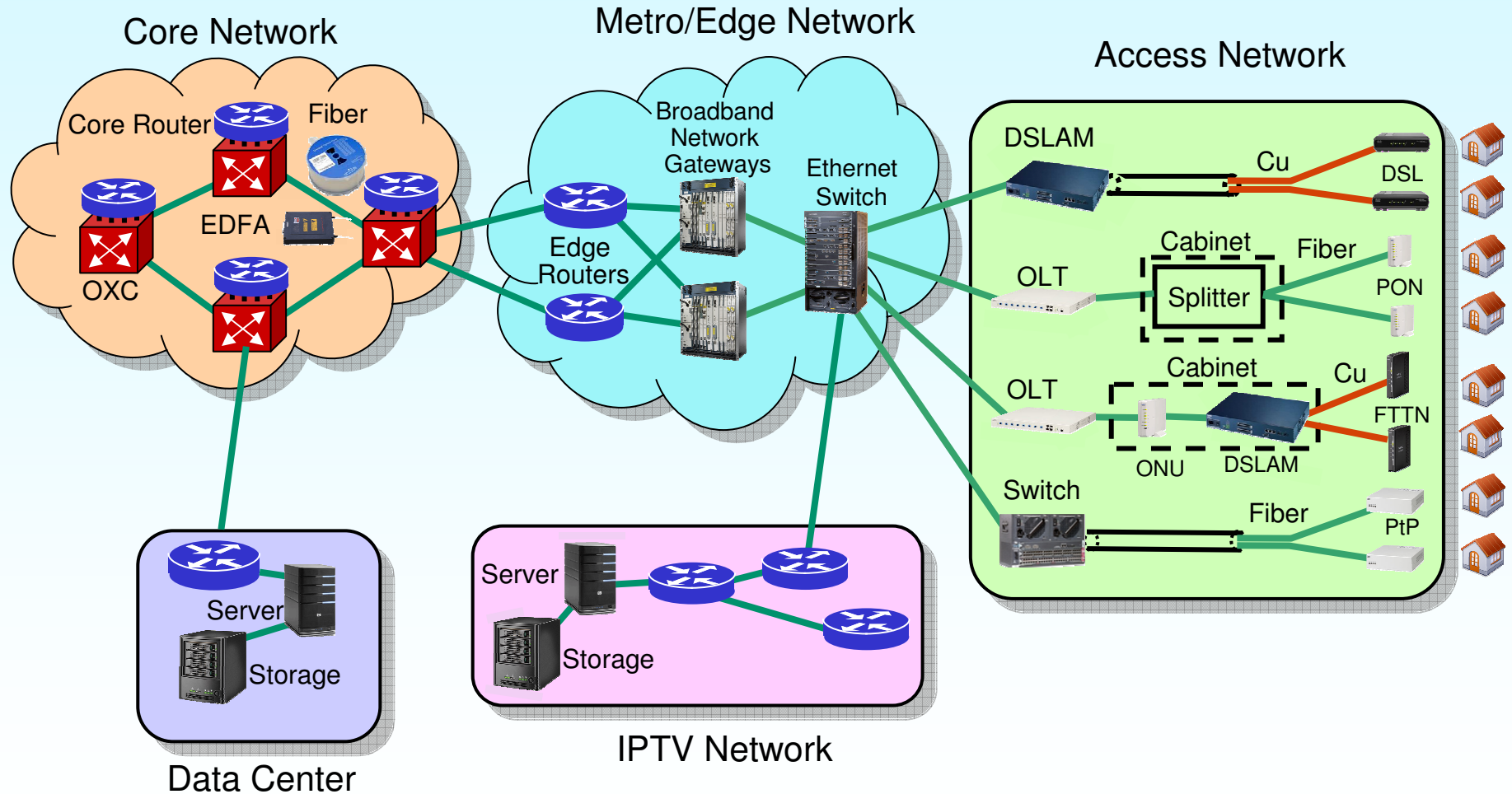


## Why is Energy Important?

- Operational Expenditure (OPEX)

- Greenhouse Impact

- Energy-limited capacity bottlenecks ("hot spots")

# Calculating Energy Consumption of the Internet

- A model to estimate energy consumption of the Internet
    - Core, metro, and access networks

- Where does the energy go?

- What happens as traffic grows?

- Towards an energy efficient Internet

# Network Energy Model

## Tier 1 Full-Service ISP Network



Core Network

Metro/Edge Network

Access Network

Core Router

Fiber

EDFA

OXC

Broadband Network Gateways

Ethernet Switch

Edge Routers

DSLAM

Cu

DSL

OLT

Cabinet

Fiber

Splitter

PON

OLT

Cabinet

Cu

ONU

DSLAM

FTTN

Switch

Fiber

PtP

Server

Storage

Data Center

Server

Storage

IPTV Network

# Estimating Energy Consumption

- Choose an access data rate (capacity per user)

- Carry out paper design of network

- Calculate the power consumed by the network per user

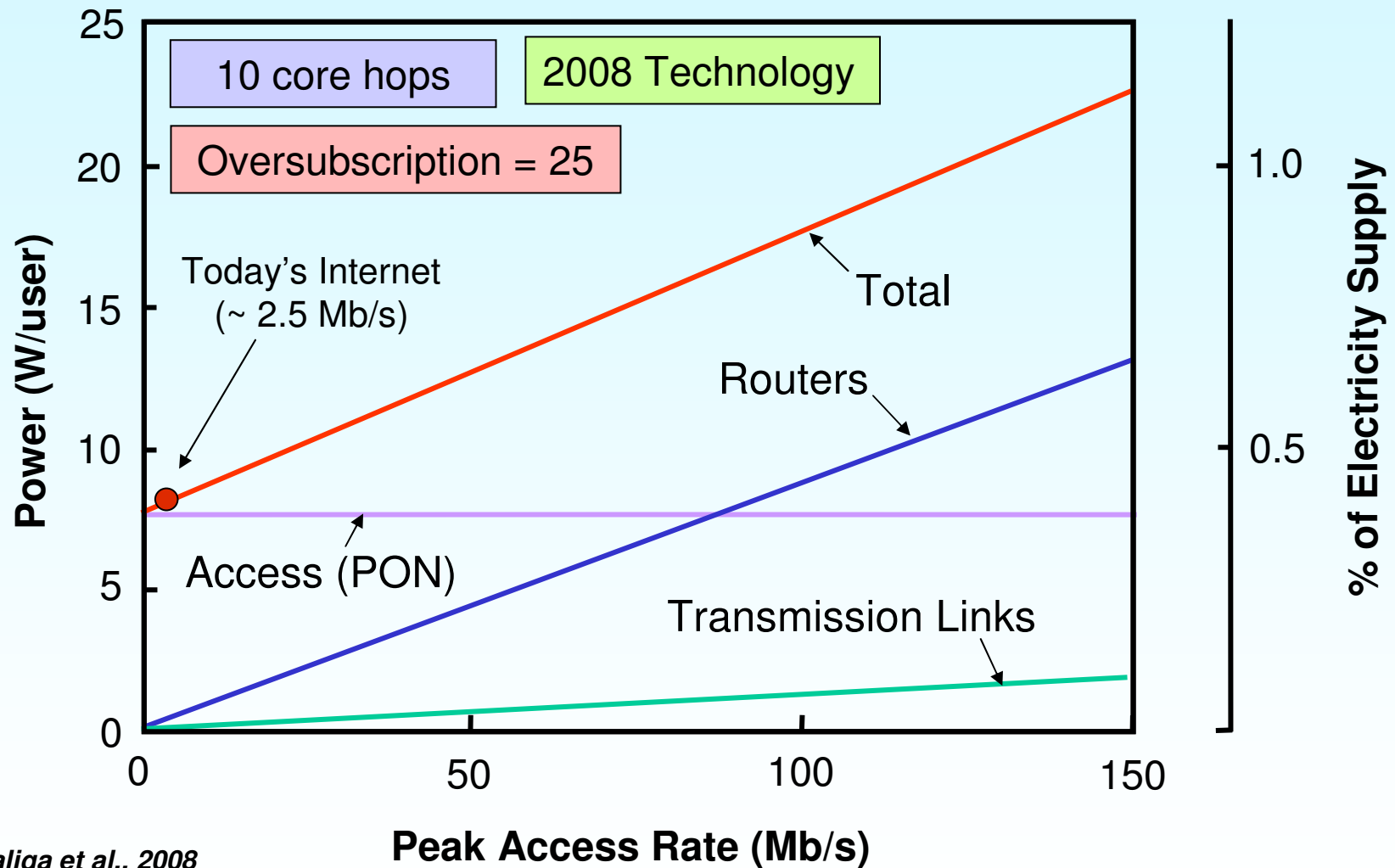- Repeat for all access rates

Oversubscription

$$M = \frac{\text{Peak access rate sold to user}}{\text{Capacity per user}}$$
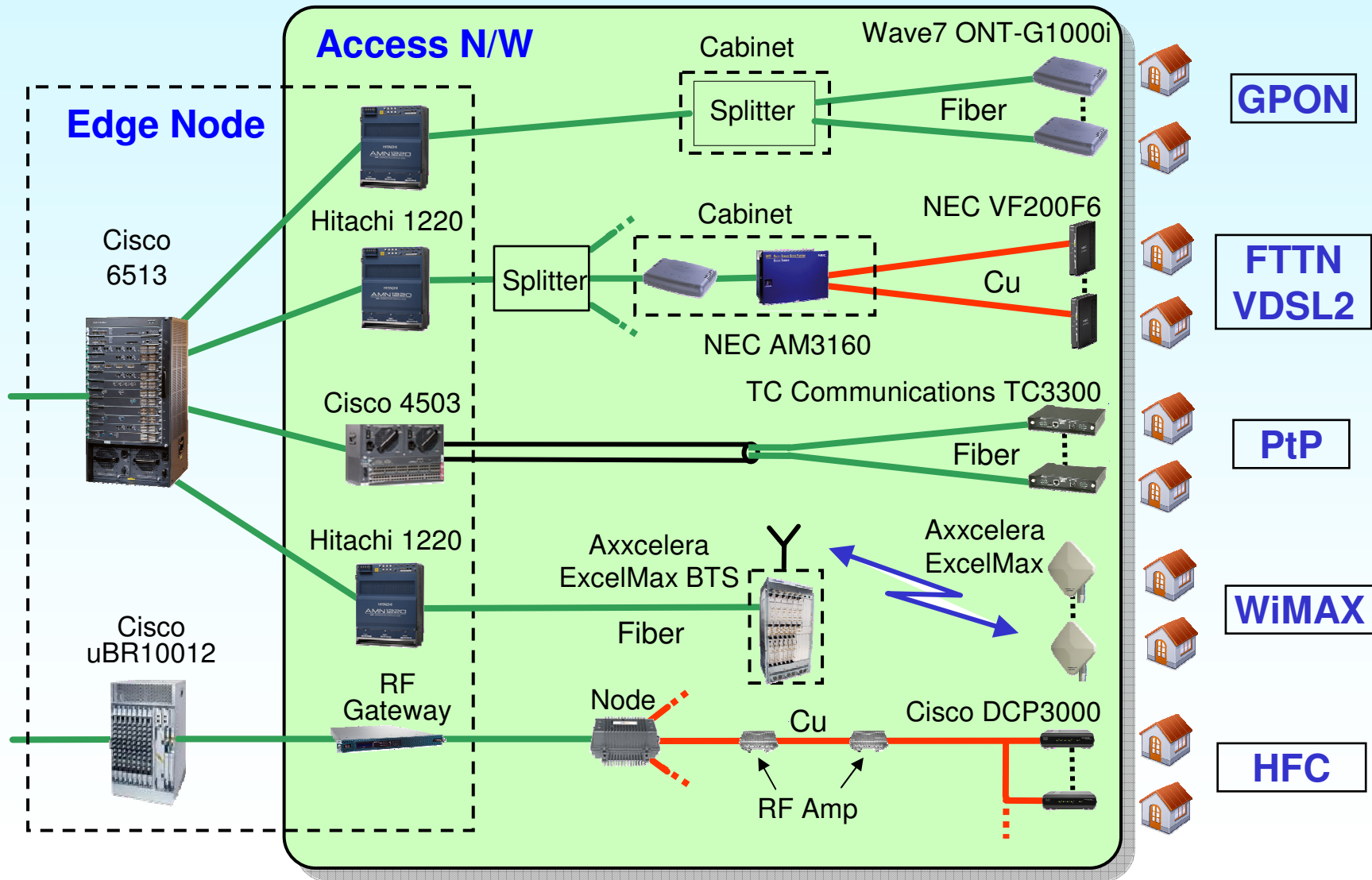
~ 2.5 Mb/s in 2008

$M = 25$

~ 0.1 Mb/s in 2008
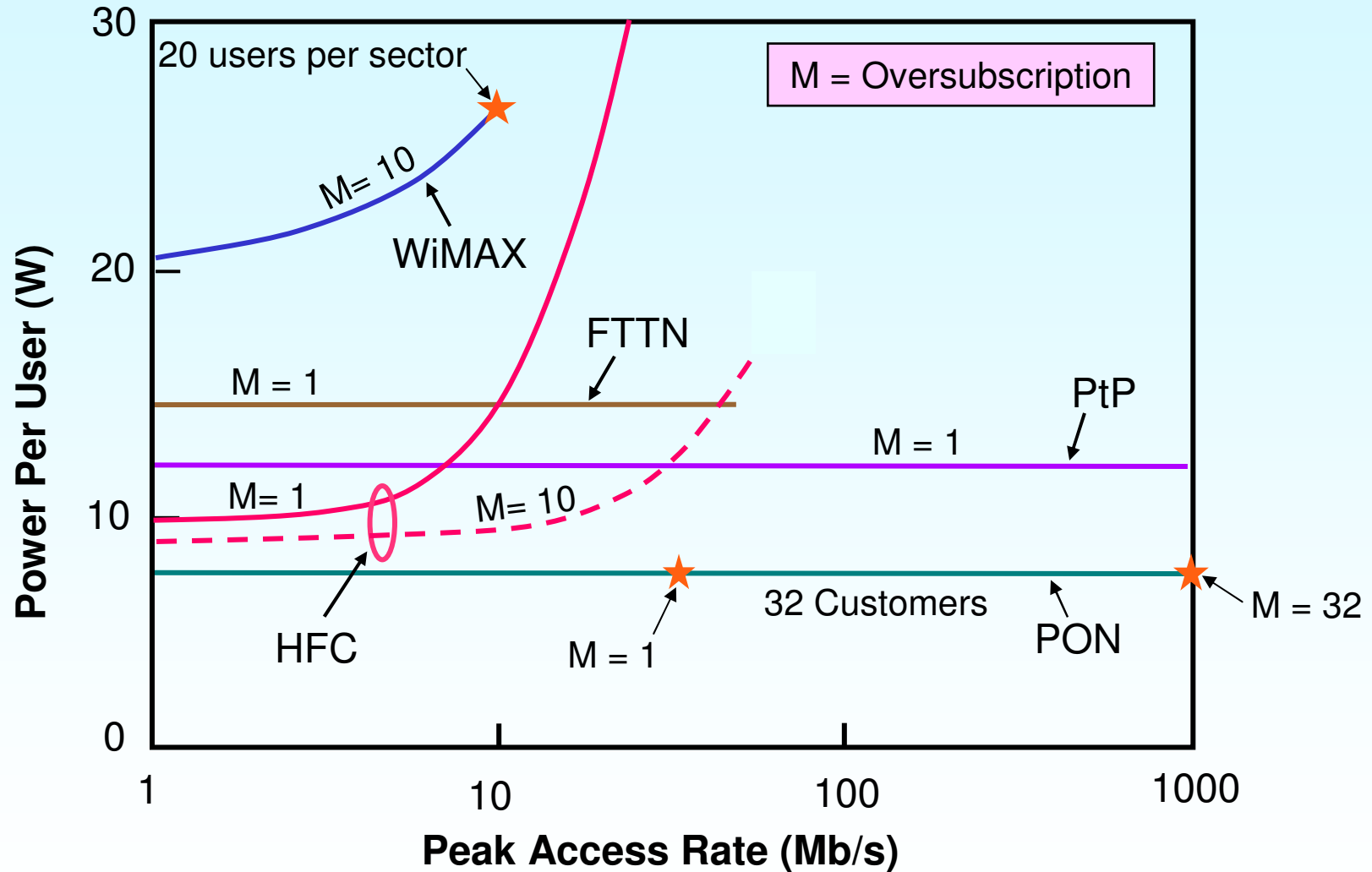
# Power Consumption of IP Network

Baliga et al., 2008

# Power Consumption in Access Networks

# Power Consumption in Access Networks

# Some Observations

- **Access network dominates at low rates**

- **Network routers dominate at higher rates** ⬅

- **Transmission Links consume a small percentage of the total power**

- **Possible approaches to controlling growth in energy consumption:**
  - **Improve electronic technology**
  - **New architectures (Optical bypass)**
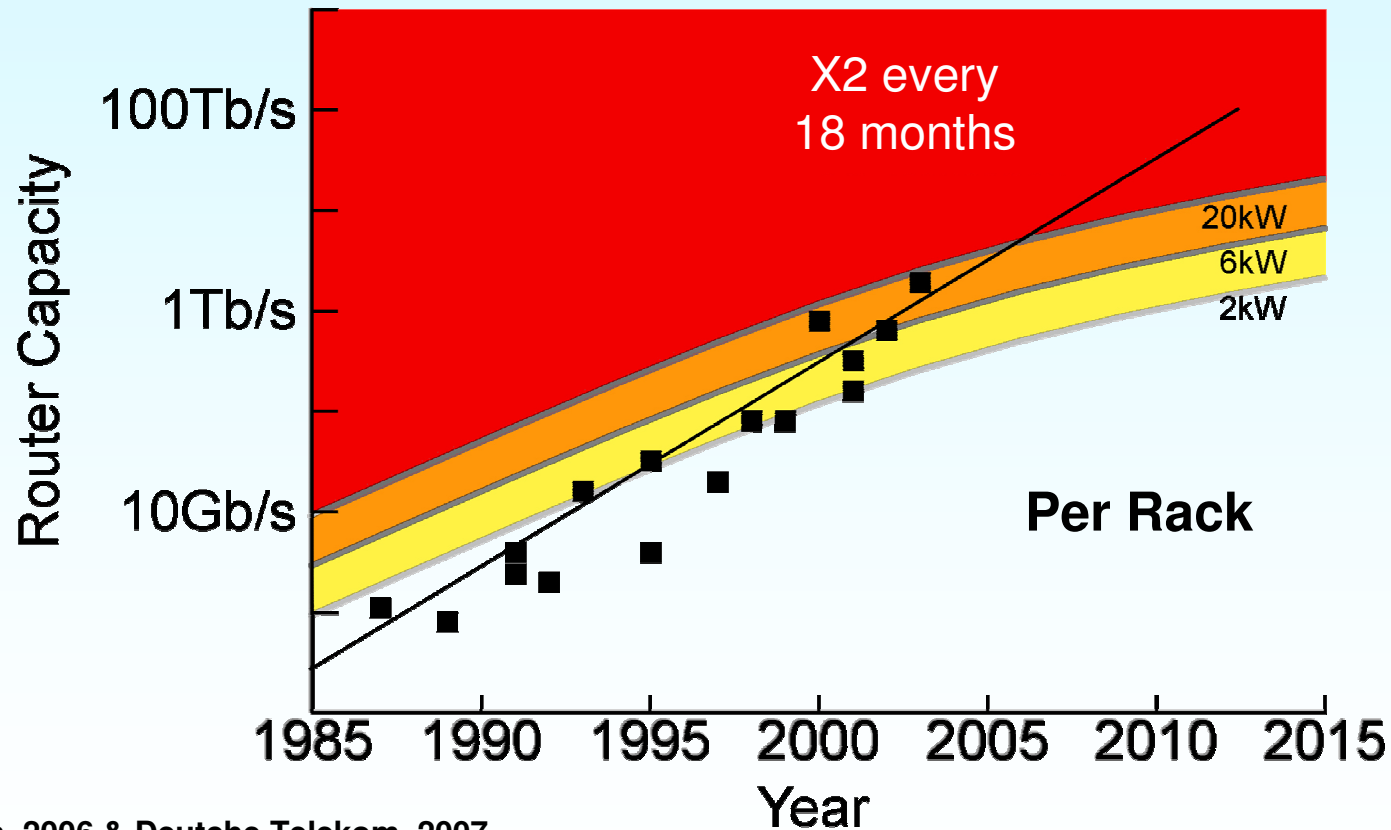  - **New protocols ("low energy" states)**
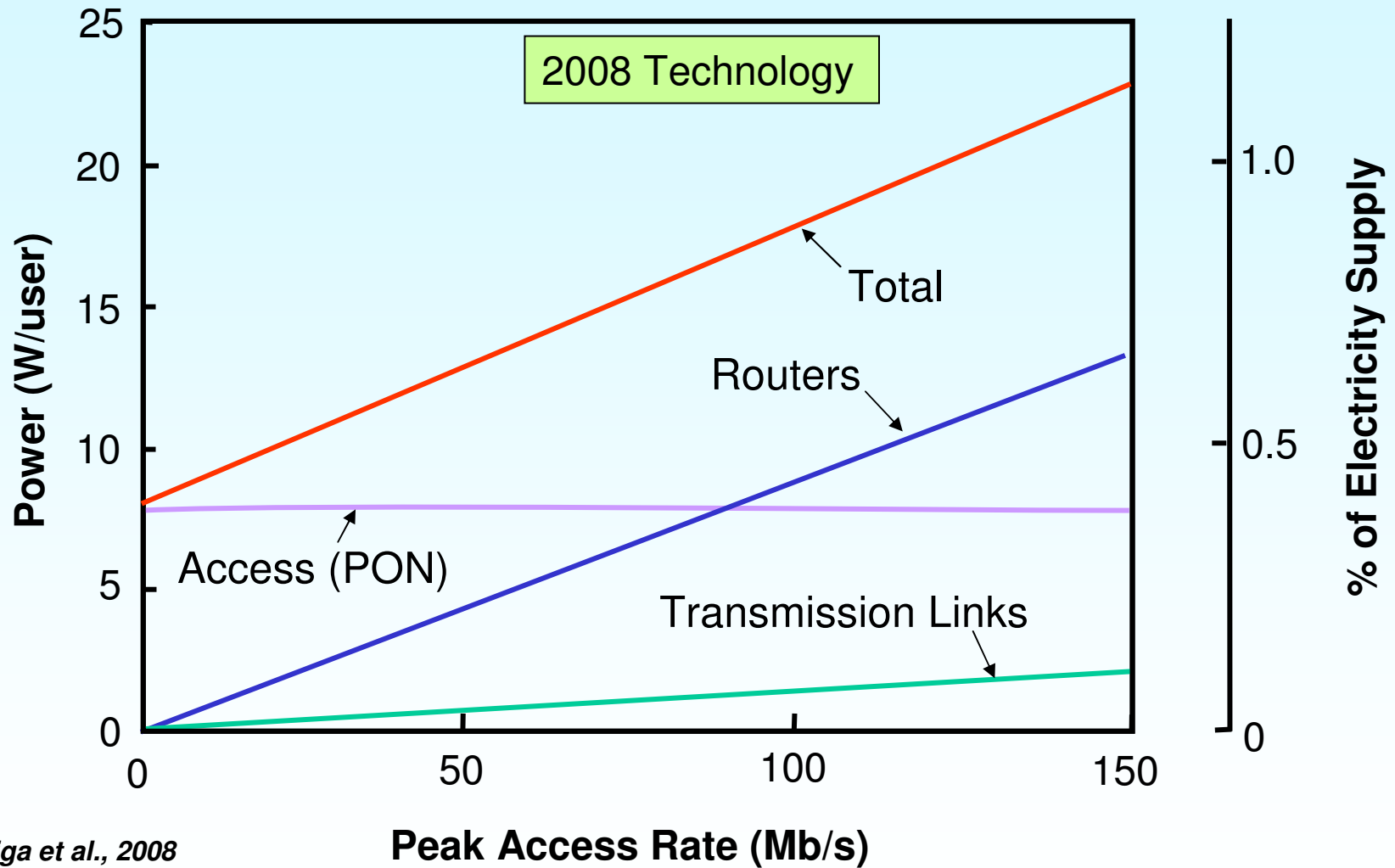
# Router Capacity Growth
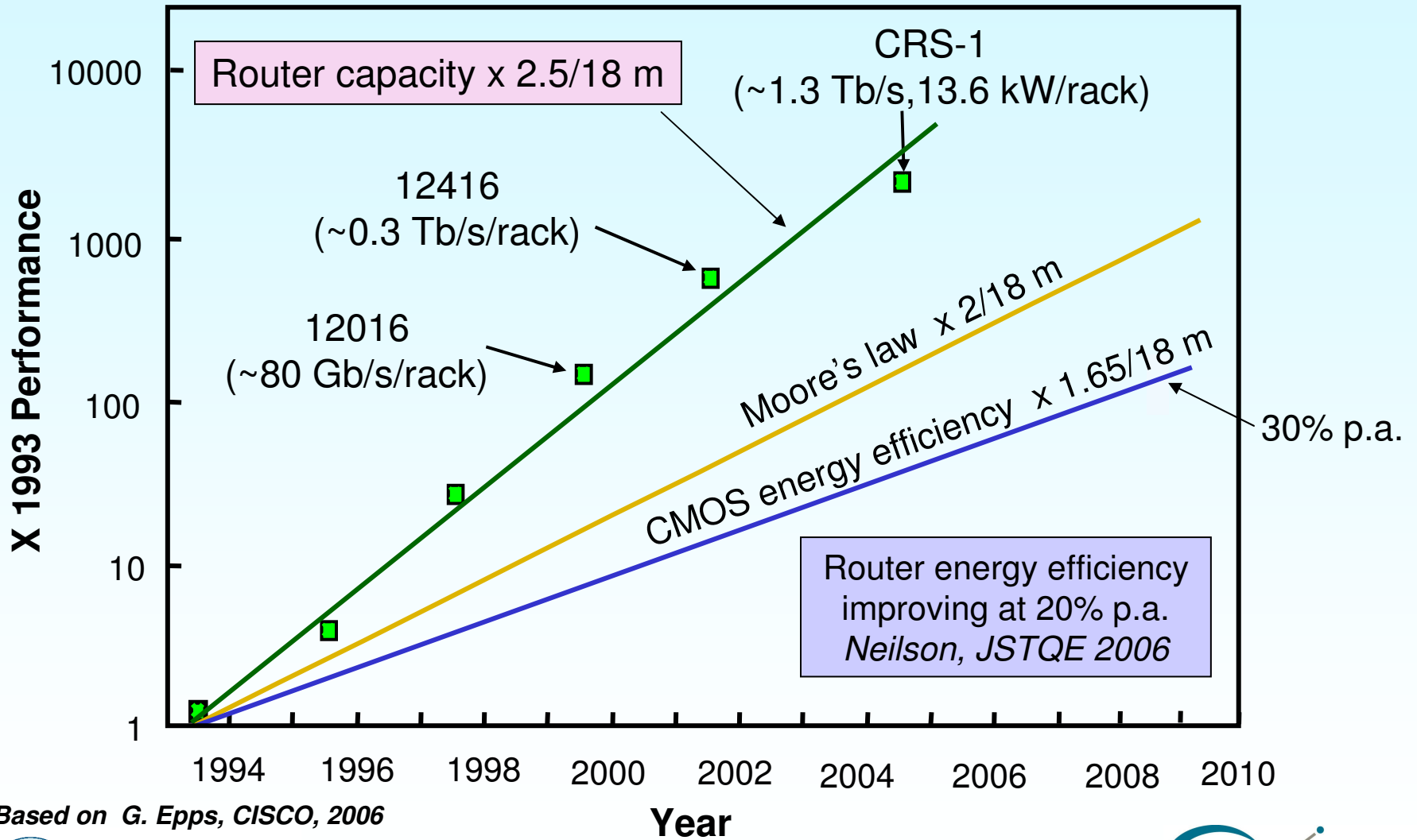
# The Energy Bottleneck

- Router energy consumption is reaching the limits of air cooling
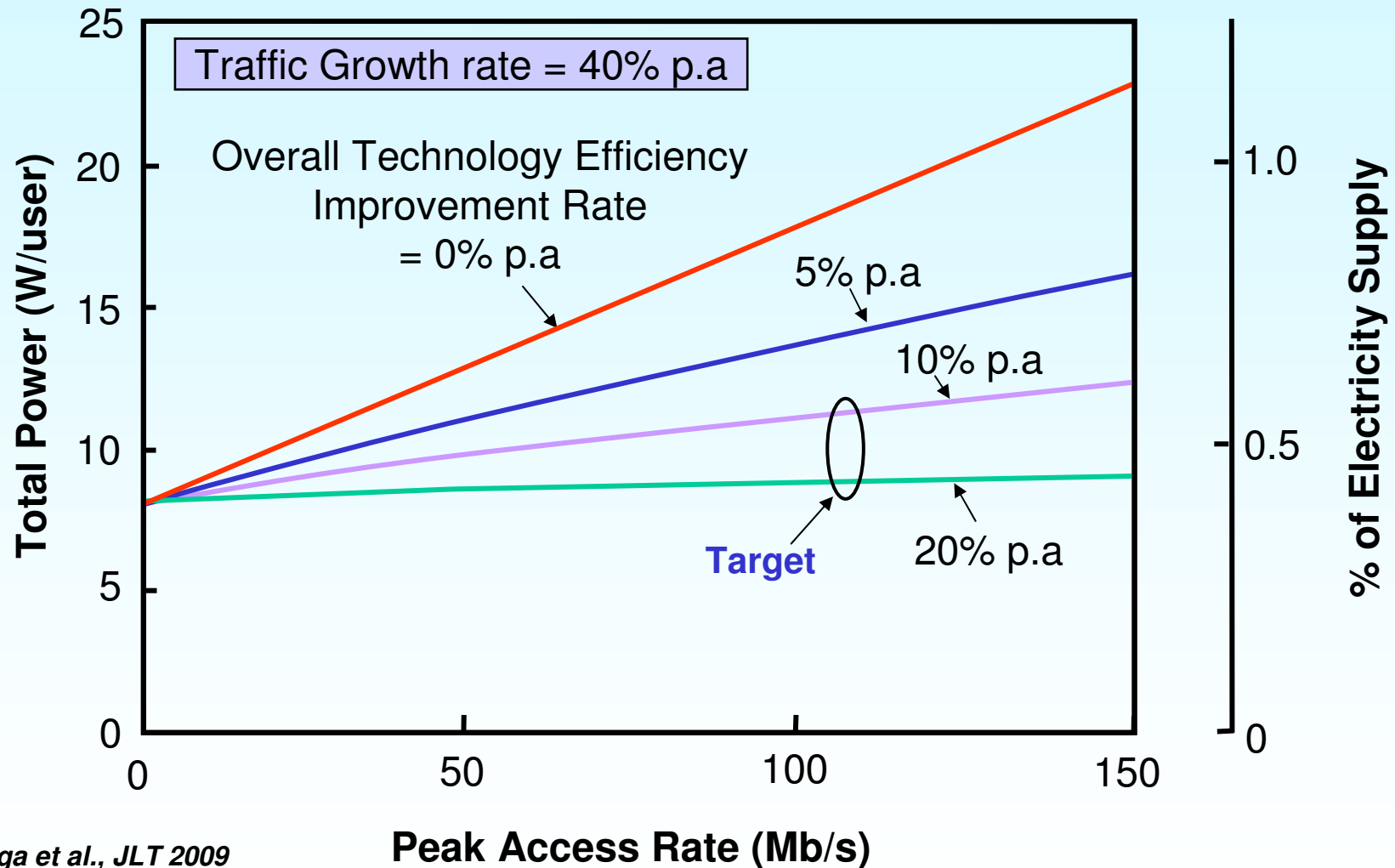  - Cisco CRS-1 (largest core router available)



**Neilson, 2006 & Deutche Telekom, 2007**
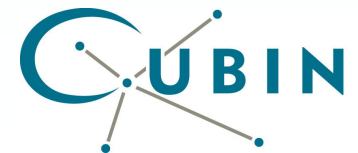
# Effect of Efficiency Gains?



Baliga et al., 2008
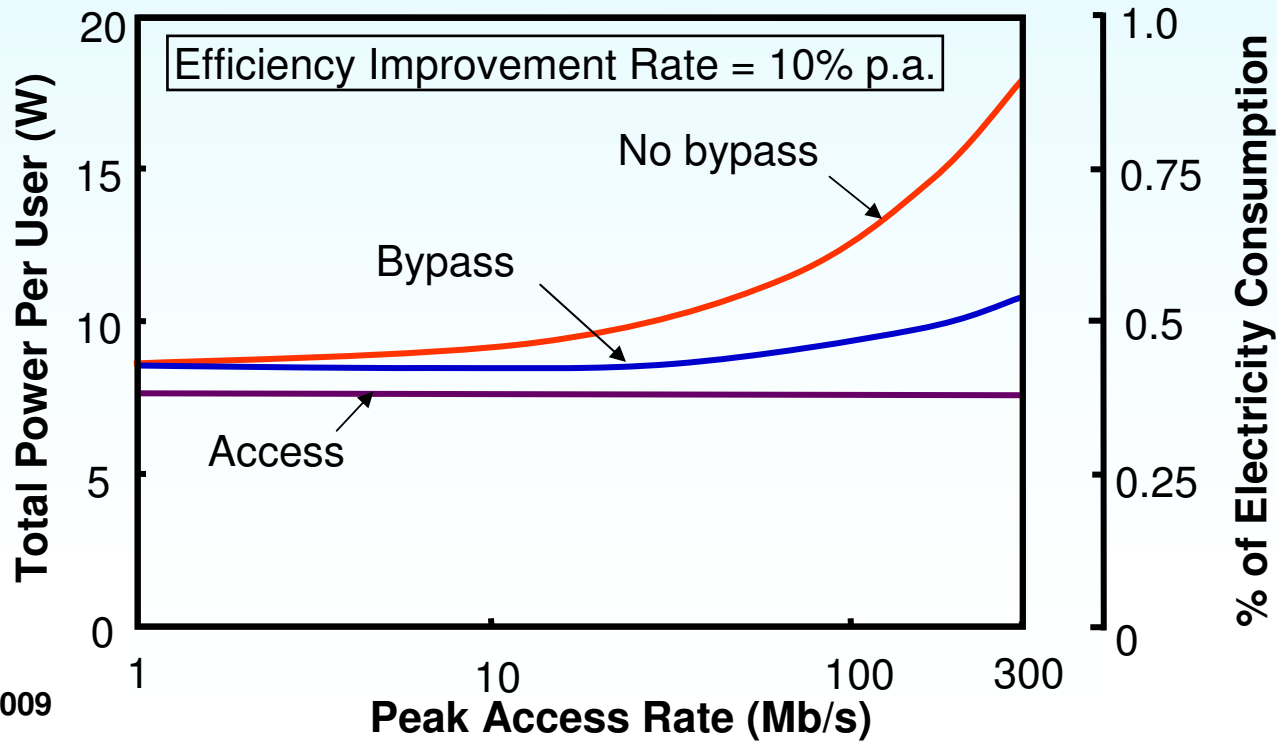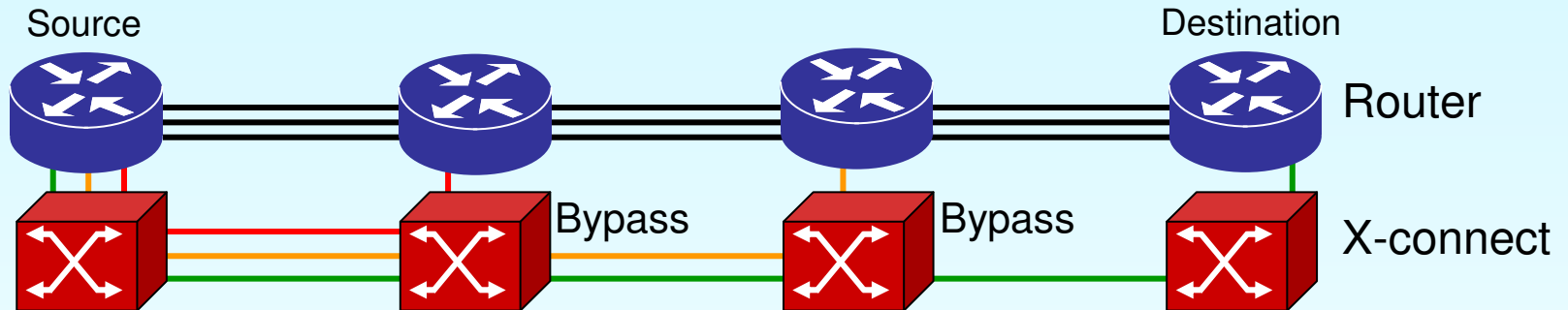
# Improvements in Technology Efficiency



Baliga et al., JLT 2009

# Improvements in Network Architecture

## Optical Bypass

# Summary – Where to in the Future?

- Energy consumption of the Internet is small (0.4%), but will approach 1% in the future

- Internet energy consumption dominated by
  - Access network today
  - Core network in the future

- A multi-disciplinary approach is required to build a green Internet:
  - Improved efficiency in electronic and photonic devices
  - Improved architectures