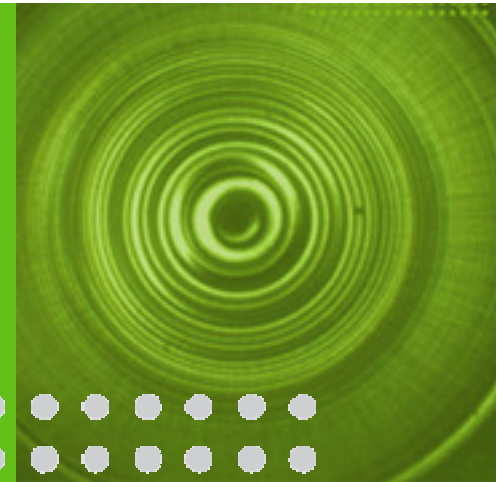


# Greening the Internet with Content-Centric Networking



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# Internet = Content Dissemination

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Today's Internet is all about “content dissemination”

- IPTV, Hulu, Netflix, user generated content (Facebook, Twitter, YouTube)

Today's strategies for meeting ever increasing user demands:

- Service providers (e.g., Google) — enlarging data centers
- Network providers (e.g., AT&T) — increasing network capacity
- and some service providers even build their own private network (e.g., Google, Microsoft)

**Content dissemination consumes lots of energy, ranging from servers in data centers to network routers to home PCs (and still increasing).**

# Energy-Aware Content Dissemination Today

Most research focused on energy consumption/optimization at data centers

- Dynamic resource provisioning (e.g., DVFS, sleeping)
- Request routing to a data center with lower \$/J
- *Energy-proportional computing*: power consumption ~ utilization

Energy consumption/optimization of networking devices

- Current networking devices show poor energy efficiency (e.g., high idle power regardless of utilization)
- Researcher is seeking for *energy-proportional networking*
  - Low power idle/sleeping mode, dynamic rate adaptation (e.g., DVFS, tx power control), and sleeping (e.g., wake-on-LAN)

**Energy-proportional computing/networking is not enough ...  
As user demands increase, so does the power consumption.**

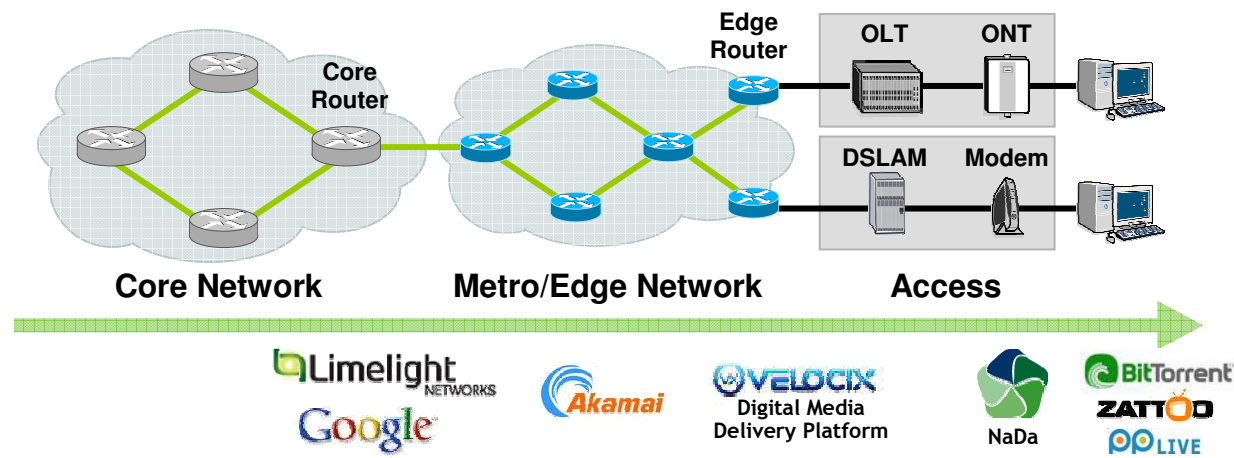
# Can Content Distribution Networks (CDNs) Help?

Pushing content closer to the users

- Hop count reduction (overall network traffic reduction) ➔ energy savings

CDN Strategies:

- Limelight — placing CDN servers near a small # of ISP core nets
- Akamai — placing CDN servers deep into a large # of ISP networks' sites
- Nano Data Center (NaDa) — home gateways (STBs/modems) as CDN servers (peer-to-peer delivery among NaDa servers)

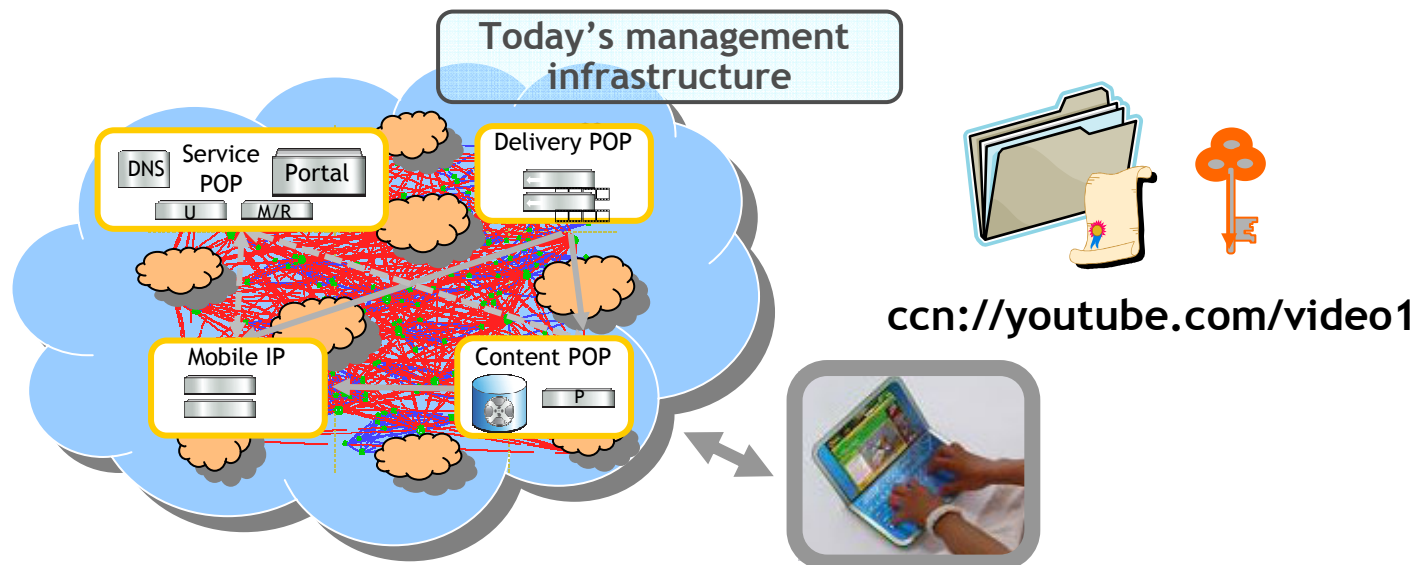


# Shifting Gears: Content-Centric Networking (CCN)

Simple, unified, flexible communication architecture

- Data has a name, not a location (+ network-wide content caching)
- Anything that moves bits in time or space can be used

CCN removes many layers of management infra (e.g., DNS, mobile IP, CDN)

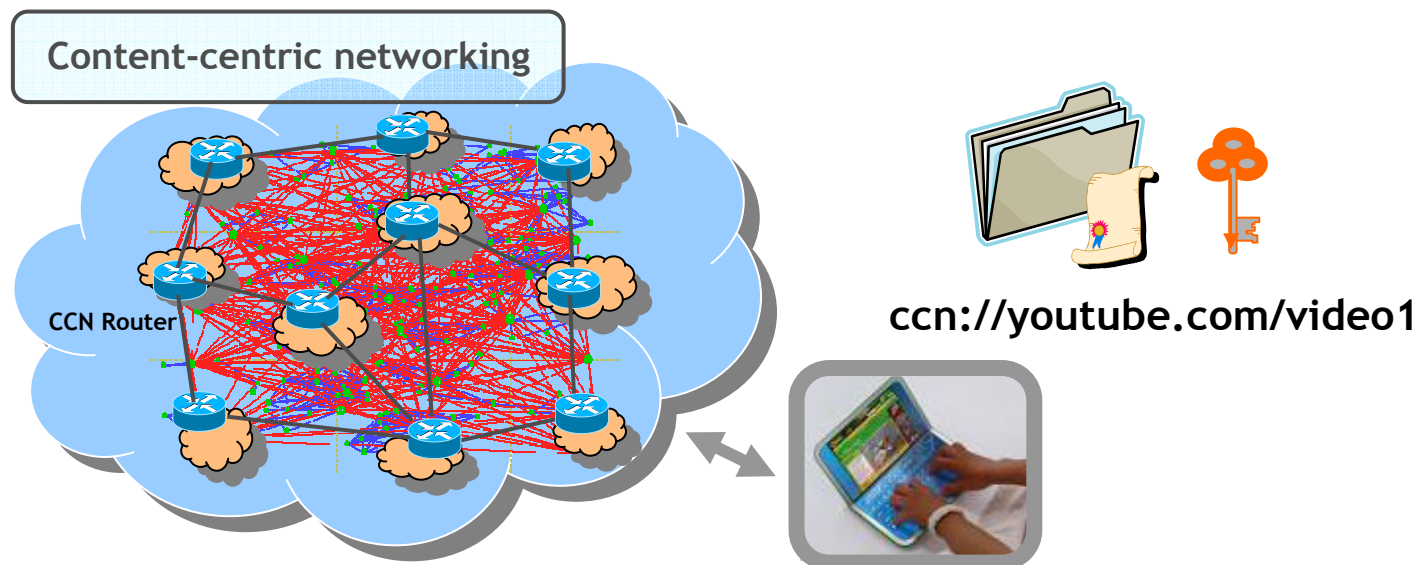


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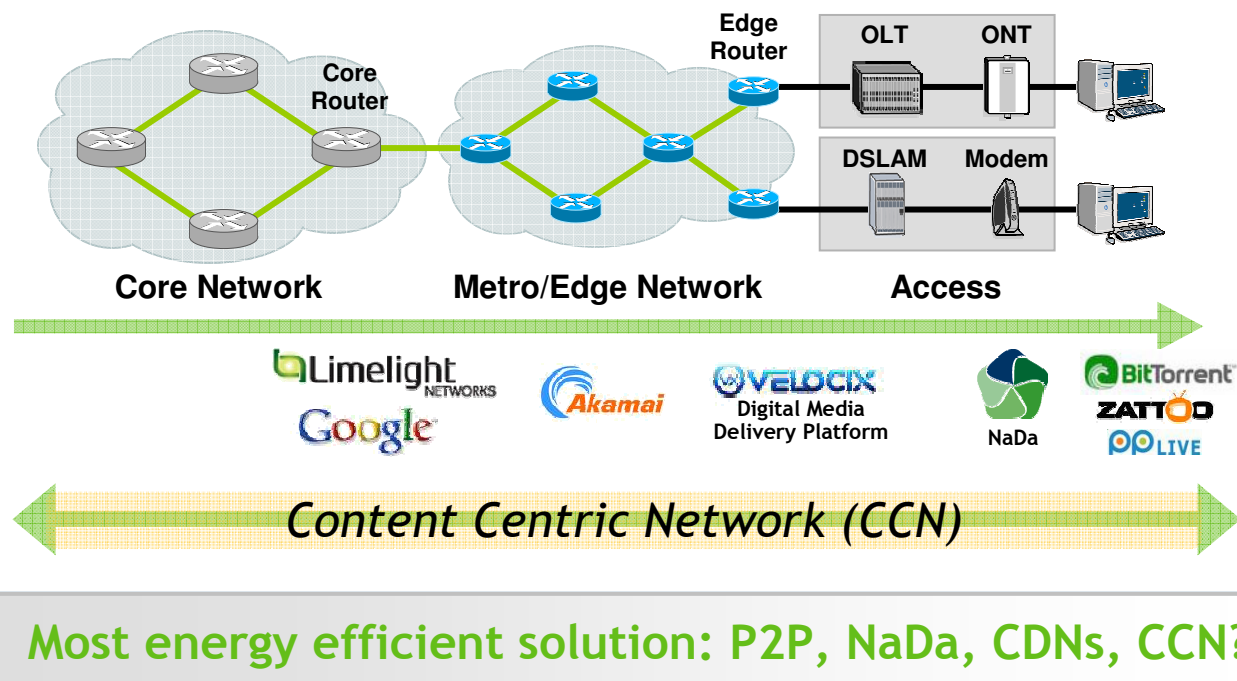


# Content-Centric Networking (CCN)

CCN enables efficient content dissemination to users

Energy efficiency of CCN content routers

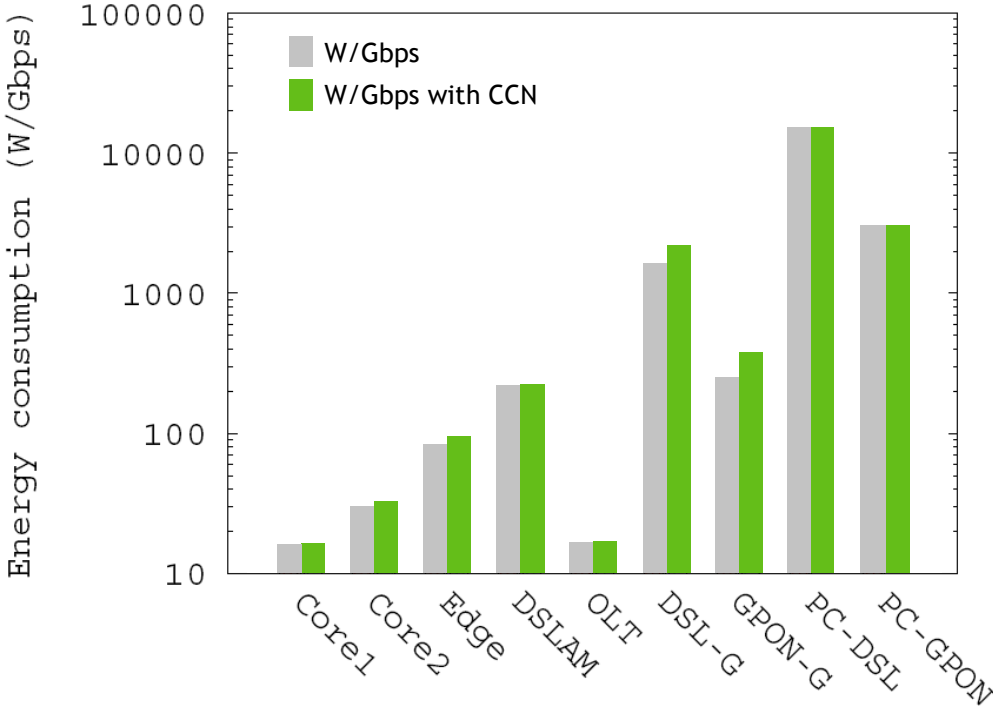
- Extra memory hierarchy that requires minimal power draws
- E.g., Memory 4G ~ 10W, SSD 32G ~ 1W, Disk ~ 12W



# Energy Efficiency of Networking Devices: A Survey

Metric: W/Gbps (= nameplate power / max bandwidth)

- Assumption: energy-proportional networking



Core1: Cisco CRS 1 = 4834W/320G  
 Core2: Cisco CSR 12000 = 800W/28G  
 Edge: Cisco 7507 = 400W/5G  
 DSLAM: Zyxel IES-500M = 800W/3.84G  
 OLT: Fujitsu FA2232U = 400W/10G  
 DSL Modem: D-Link DSL 2320B = 15W/10M  
 ONT: Allied Data = 12W / 50M  
 PC: Dual Core = 150W / 10M or 50M

**Energy consumption increases exponentially as content is being moved closer to end users.**



# Evaluation

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## Methodology:

- Traceroute data set—top 20 content providers ranked by Alexa
  - Querying these providers from 18 different traceroute servers in the US
- Tier 1/Non-Tier 1 classification (i.e., edge vs. core router)
  - Based on a publically available Tier-1 ISP list

## Metric:

- Energy consumption (Joule) for downloading 1 Gbit of content (125MB)

## Scenarios:

- CCN-enabled core/edge nodes: 0% (NonCCN), 20%, 100%

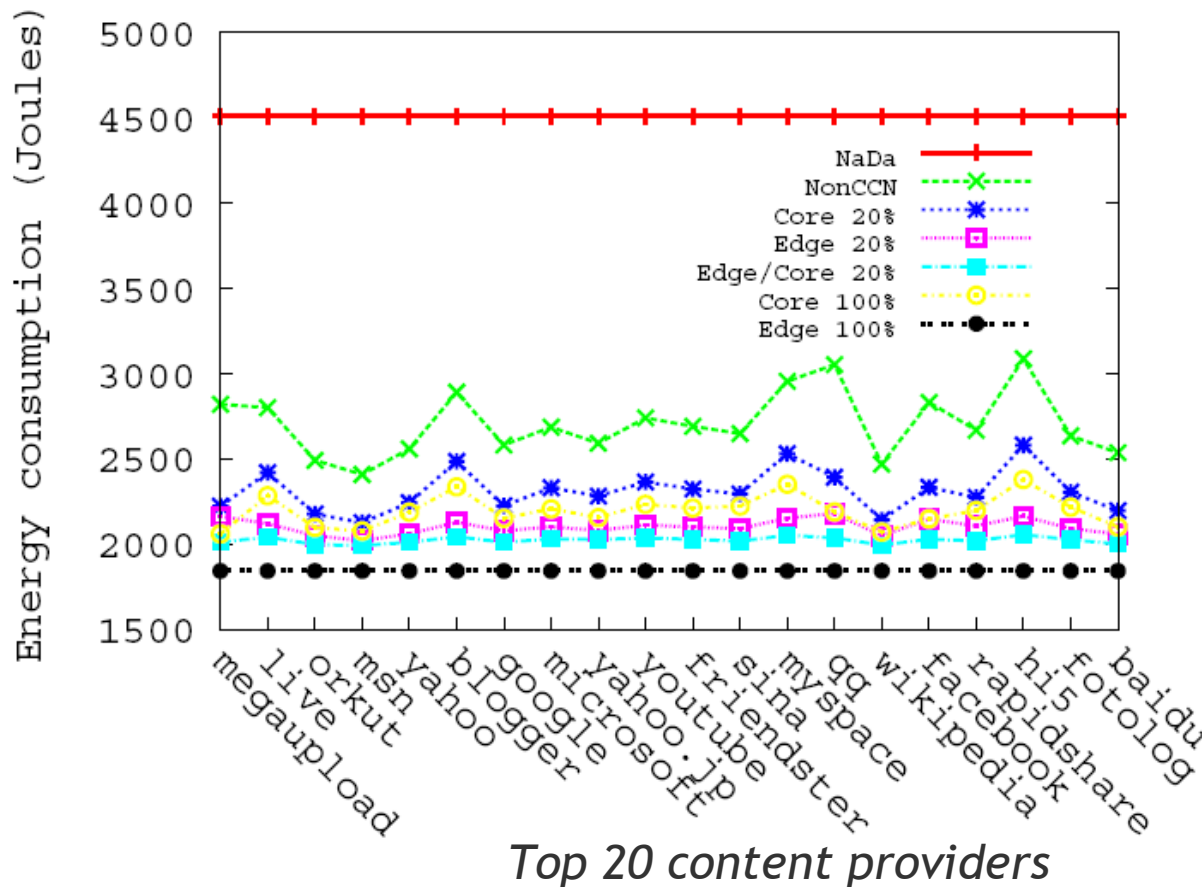
## Assumption:

- Users access popular content (100% cache hit rate)

# Energy Consumption (DSL Users)

CCN is the most energy efficient method (even with incremental deployment)

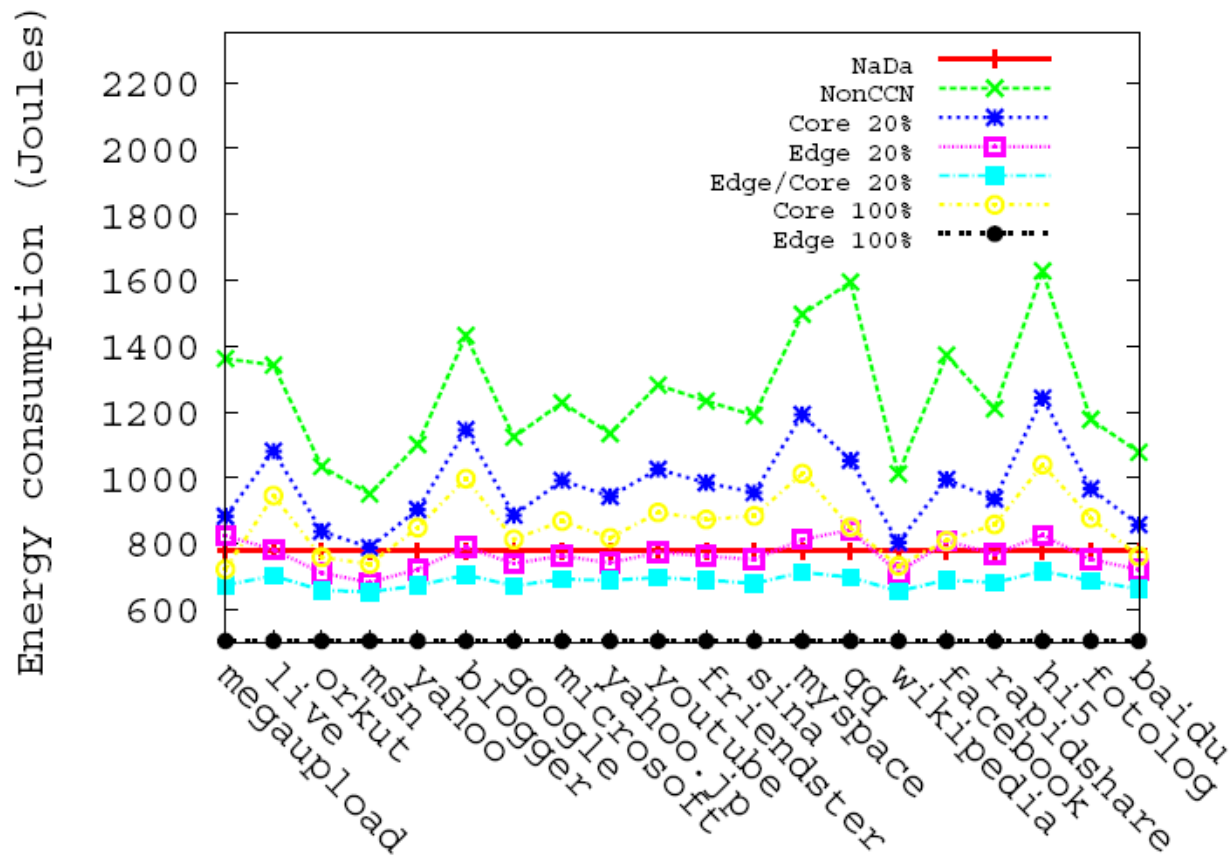
NaDa: content traverses expensive DSL gateways twice!



# Energy Consumption (GPON Users)

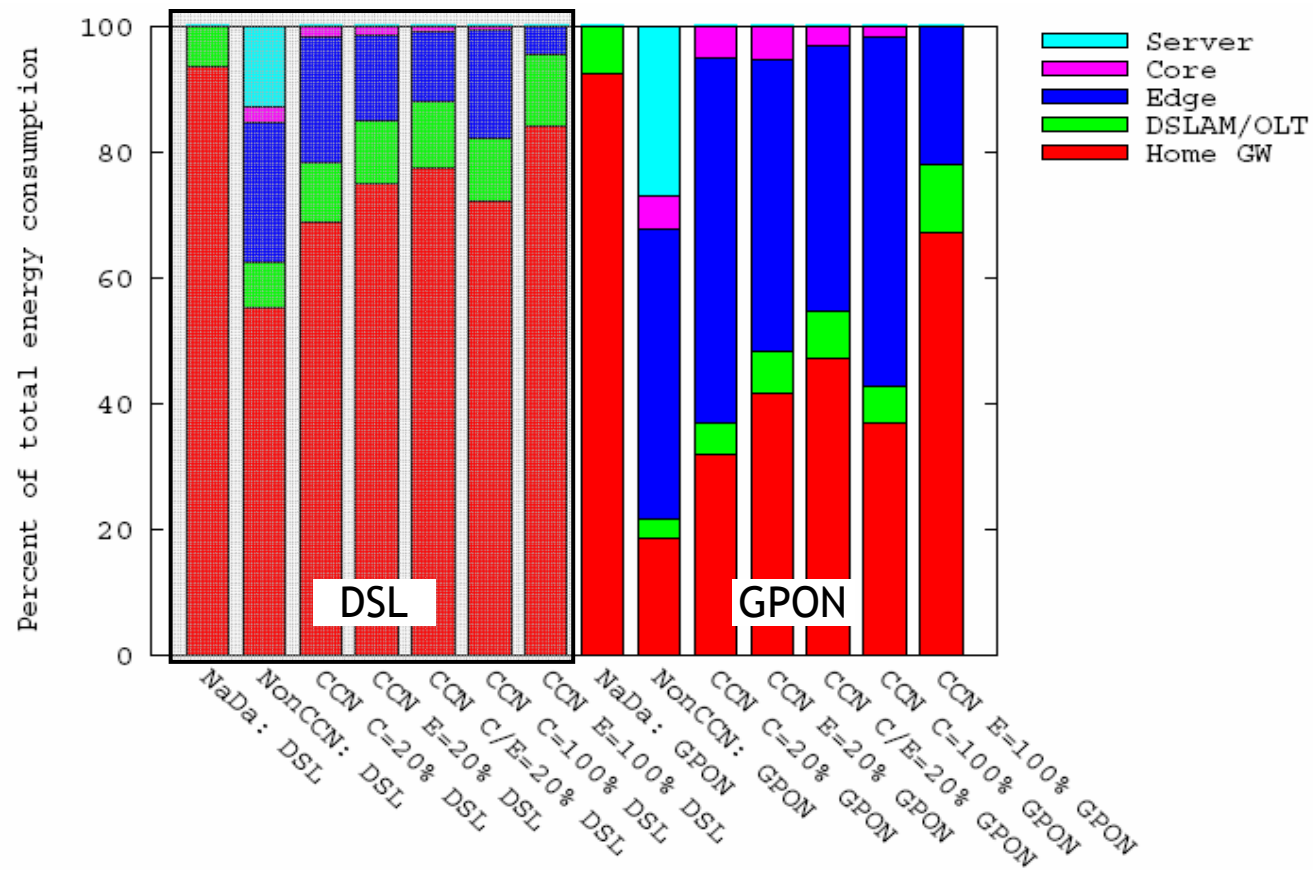
Efficiency of NaDa gets better as access link speed increases (GPON >> DSL)

CCN still outperforms when content routers are sufficiently deployed



# Energy Consumption Breakdowns

NonCCN: (DSL) GW>Edge>Server>Core>Access vs. (GPON) Edge>Server>GW>Core>Access  
 CCN: Home gateway dominates energy consumption



# Conclusion

Content distribution networks enable energy-efficient data dissemination

- E.g., traditional CDN (Akamai/Limelight), Nano Data Center (NaDa), Content-centric networks (CCN)

Energy efficiency of networking devices must be considered for energy-efficient data dissemination

- E.g., DSL-based NaDa performs worse than direct fetching from origin servers

Network-wide content caching via CCN is the most energy-efficient method even under incremental deployment scenarios

Details of our work can be found in: Uichin Lee, Ivica Rimac, and Volker Hilt. *Greening the Internet with Content-Centric Networking*, 1<sup>st</sup> Intl. Conf. on Energy-Efficient Computing and Networking, Passau, Germany, April 2010.

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