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Case studies in energy consumption of Internet services:

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CEET
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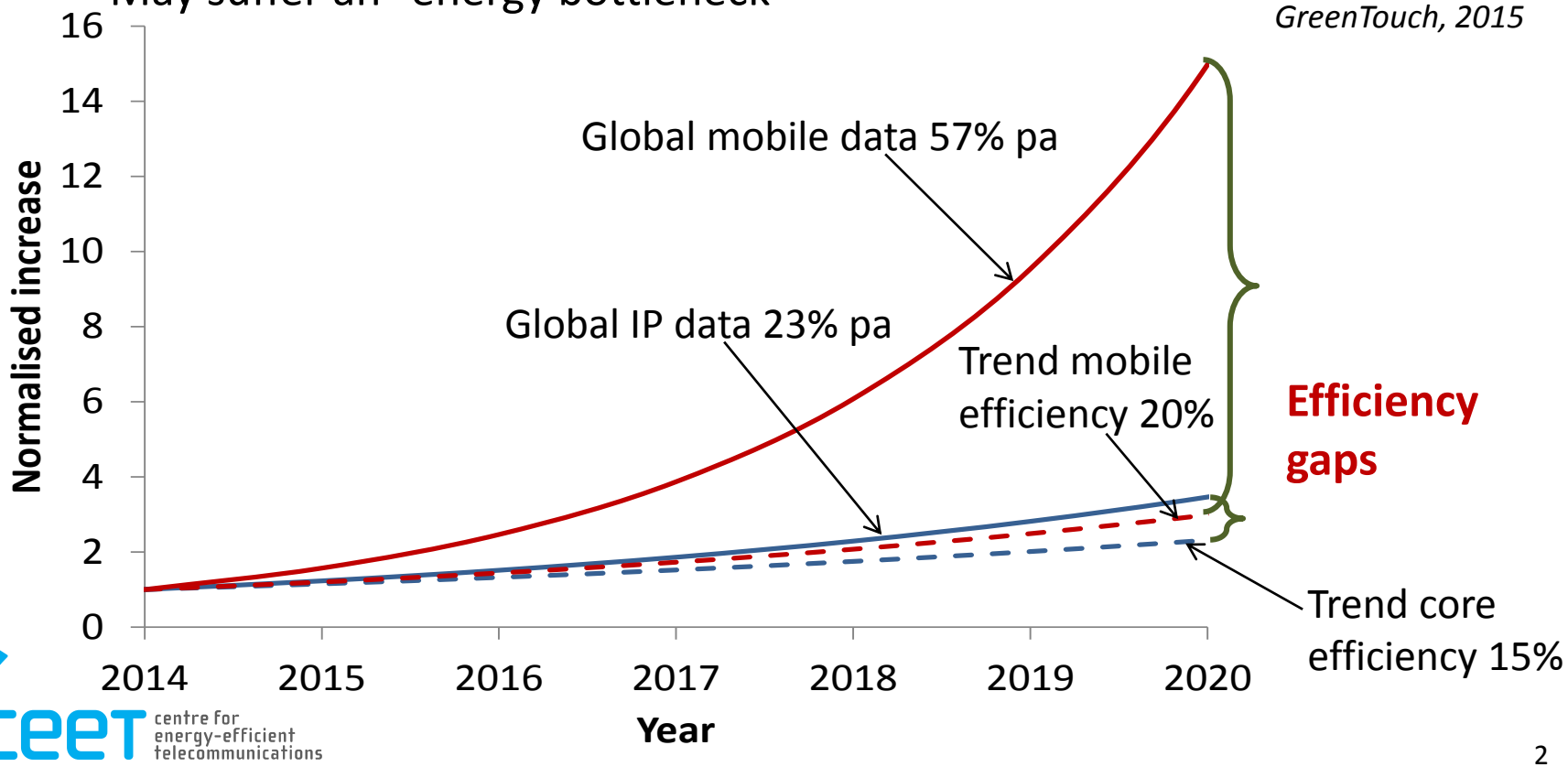
Australia

The future energy efficiency gaps

- Current data growth rate >> traditional energy efficiency improvement rate
- Technology is not keeping up with traffic growth
  - May suffer an "energy bottleneck"

Cisco, 2015
GreenTouch, 2015



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Centre for Energy-Efficient Telecommunications

- Research centre located in the University of Melbourne
- Launched in March 2011
- Partnership between Alcatel-Lucent, the University of Melbourne and Victorian State Government
  - $10 million for 2011 to 2015
  - Additional funding of $2 million has extended CEET to 1st July 2016
- World's first research centre focusing on energy-efficient telecommunication technologies
- Focus on collaboration between business and academia
- Major contributor to GreenTouch international consortium

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Case study 1: Wireless access to the cloud

- Cloud services widely promoted as greener than on-site facilities:
  - Cloud Computing – The IT Solution for the 21st Century
    - *Carbon Disclosure Project Study 2011*
  - Salesforce.com & the Environment
    - *WSP Environment & Energy 2011*
- Strong case for enterprise private cloud
- What about the public cloud?
  - Apple iCloud
  - Google drive
  - Microsoft sky drive

Consumer, interactive wireless cloud

- “automatically and wirelessly store your content”
- “automatically and wirelessly push it to all your devices”

Source: www.apple.com/au/pr/products/icloud/icloud.html

- “free Google online storage, so you can keep ..- anything.”
- “Your files .. can be reached from any smartphone, tablet, or computer.
- “.. wherever you go, your files follow..”

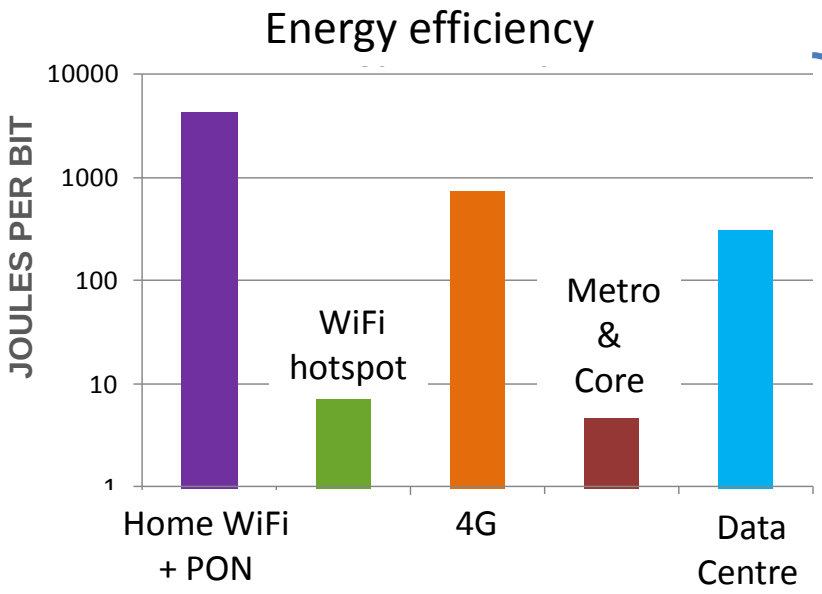
Source: www.google.com/drive/

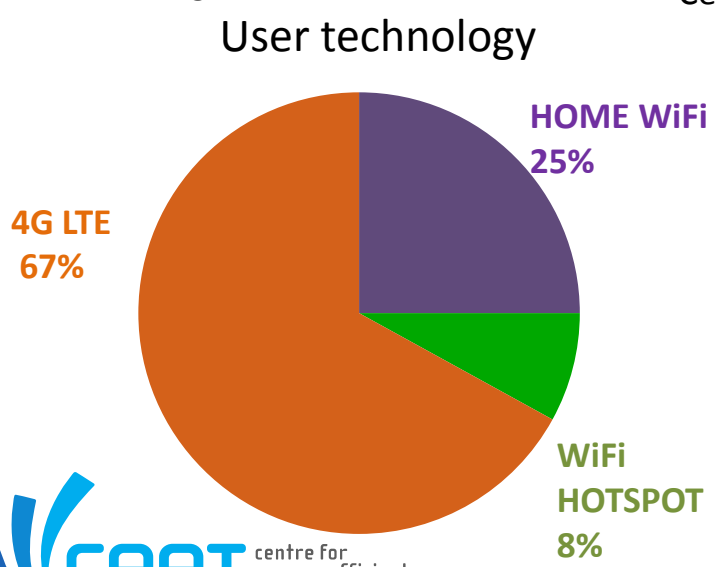
OneDrive

- “It’s like an extra hard drive that’s available from any of the devices you use. ”
- “whether you’re on your laptop on your new tablet, or on your phone .. you can get to your files in OneDrive.”

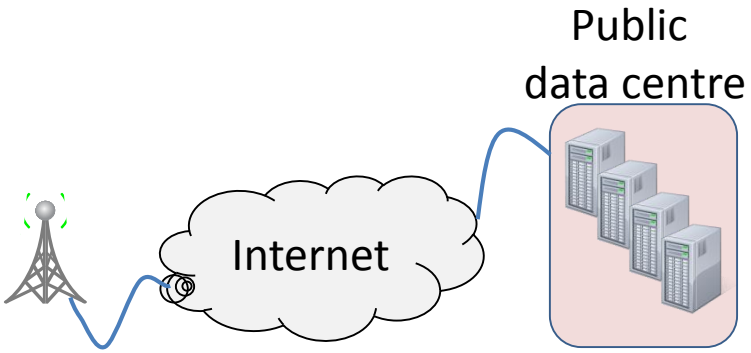
Source: windows.microsoft.com/en-us/windows-8/getting-started-onedrive-tutorial

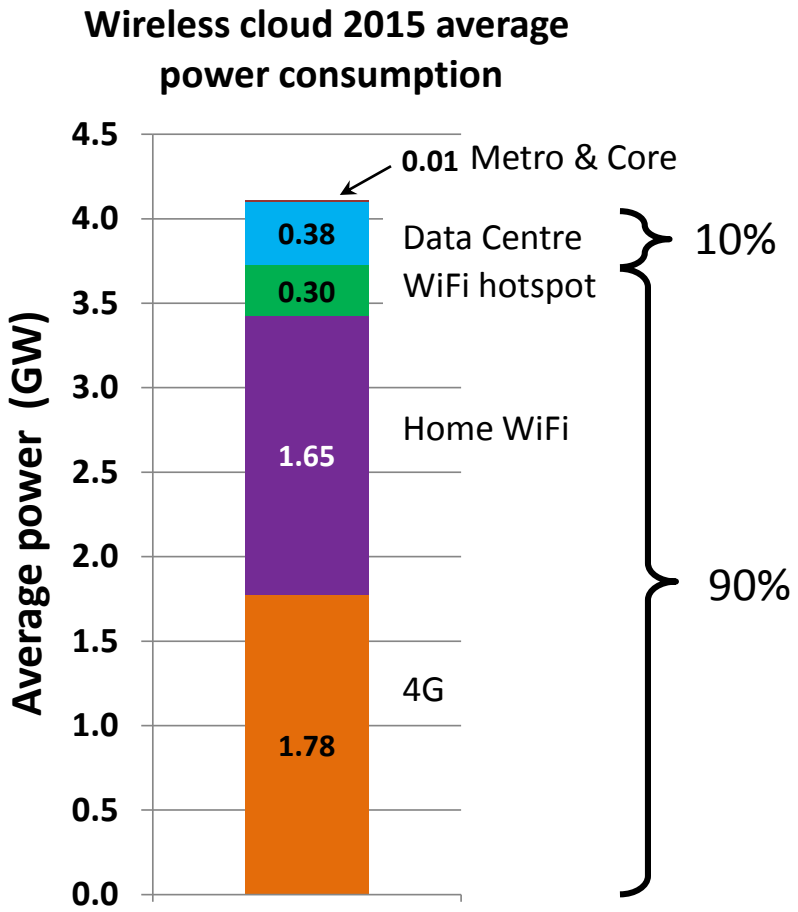
Wireless cloud power





User





CEET, 2013

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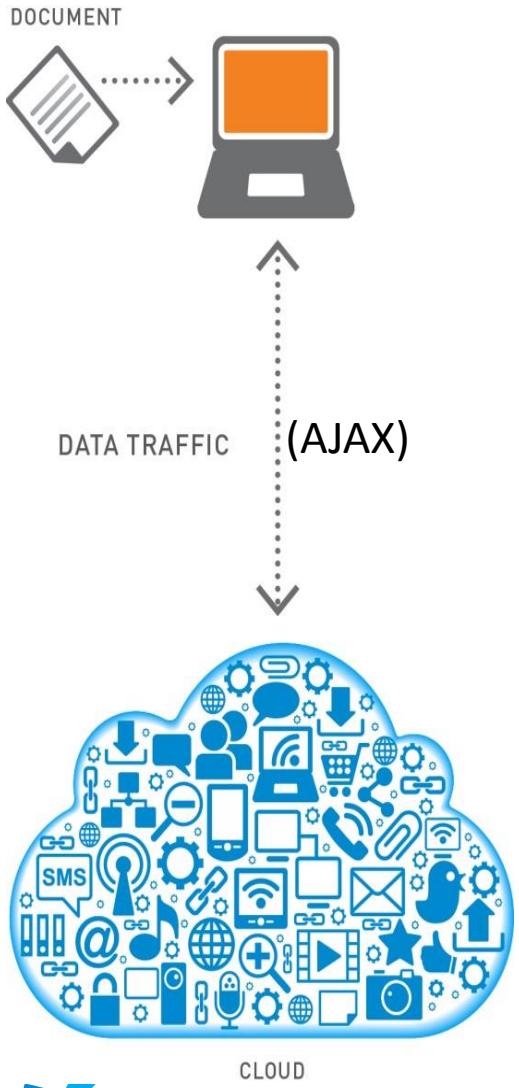
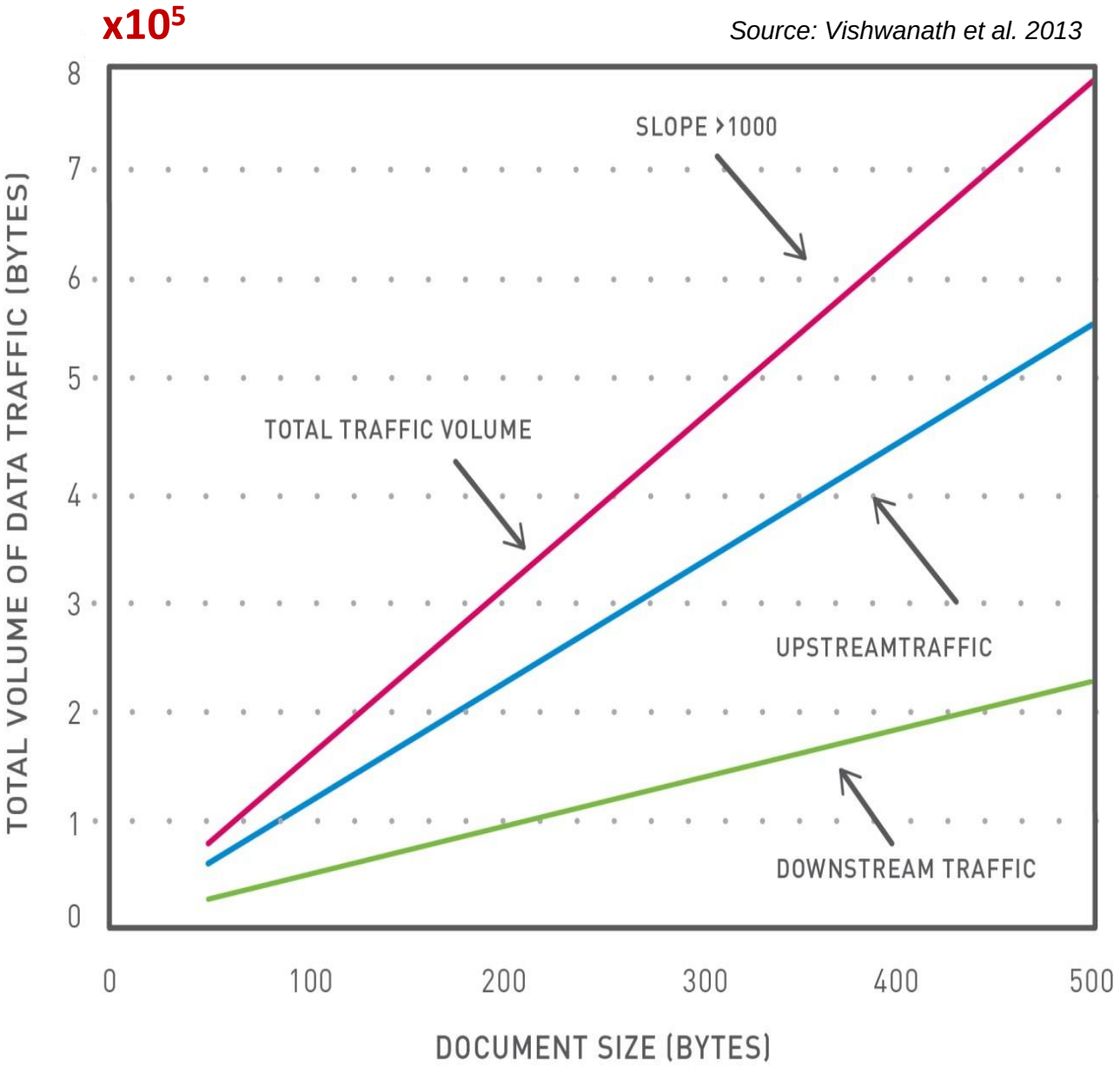
Case study 2: Interactive cloud services





Source: Vishwanath et al. 2013

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Interactive cloud services

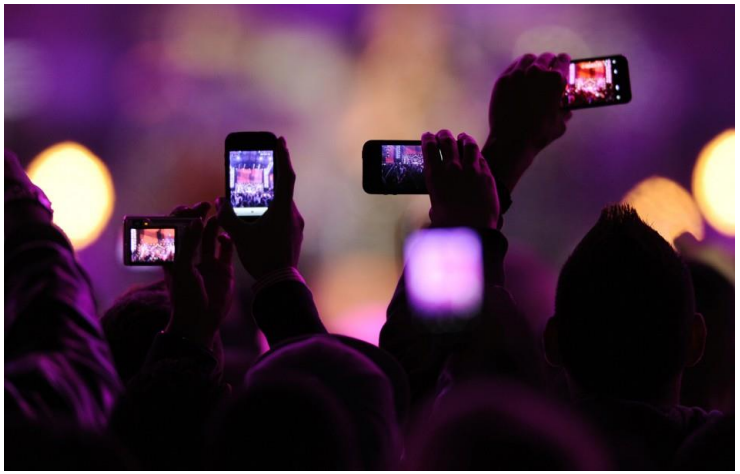
Cloud services	User goes online	User already online
3G	5.9 W	2.2 W
WiFi	3.1 W	2.3 W
Ethernet	2.5 W	2.2 W

- Local processing (not online) 0.2 W
  - An order of magnitude less power than on-line
- Decision to use the cloud depends on ...
  - Power consumption of end-user device (high vs. low)
  - Network to access the cloud (wired vs. wireless)
  - Complexity of the task (less vs. more computation)
  - Exchange of data with cloud

Case study 3: Photo sharing via cloud

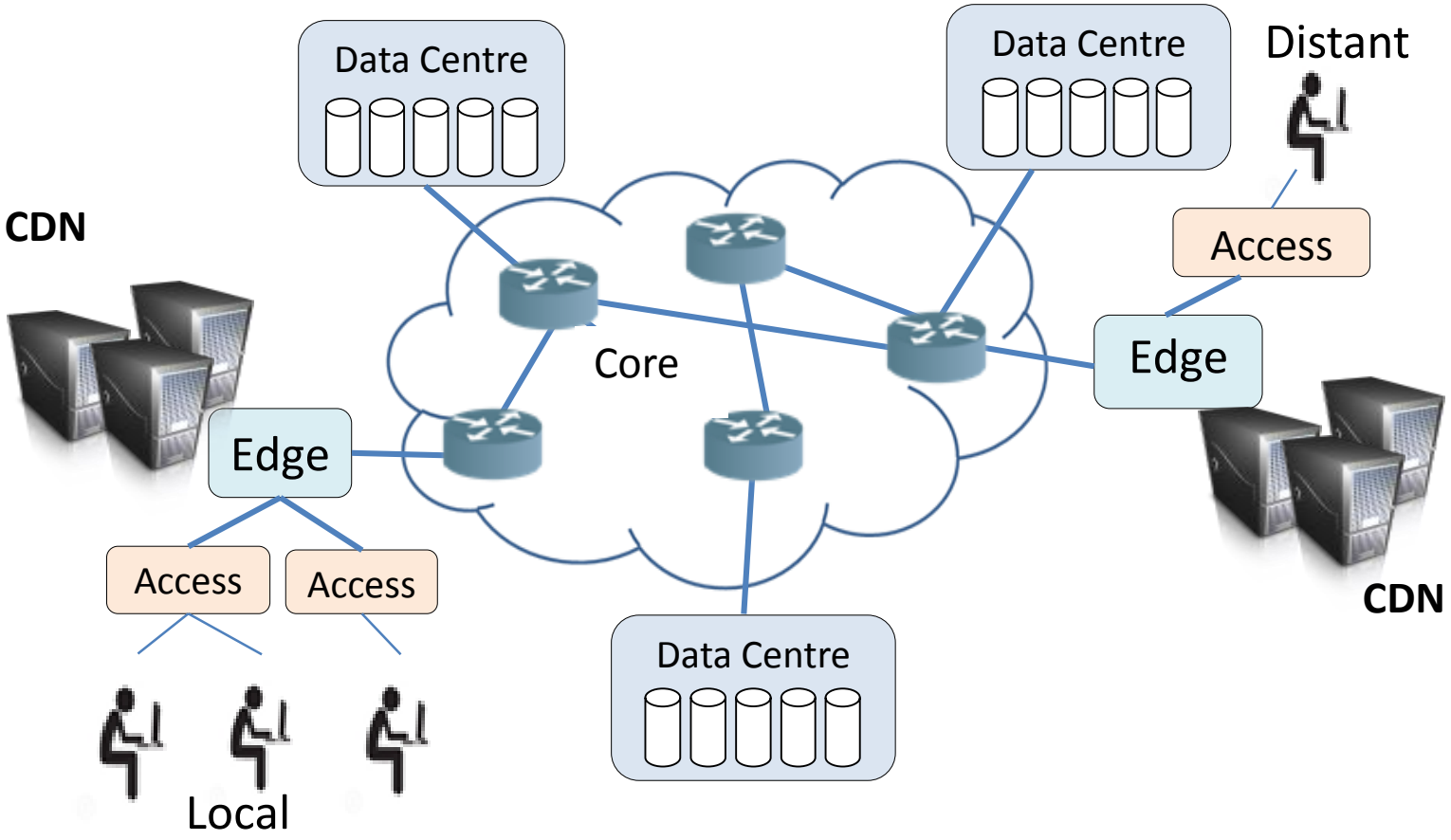
- Stunning growth of Facebook traffic:
  - 240+ billion photos
  - 350+ million photos added per day
  - 750+ million photos were uploaded over New Year's Eve
  - 7000+ Tera-Byte memory added per month
- Facebook reports its annual data center energy consumption

Then



Now

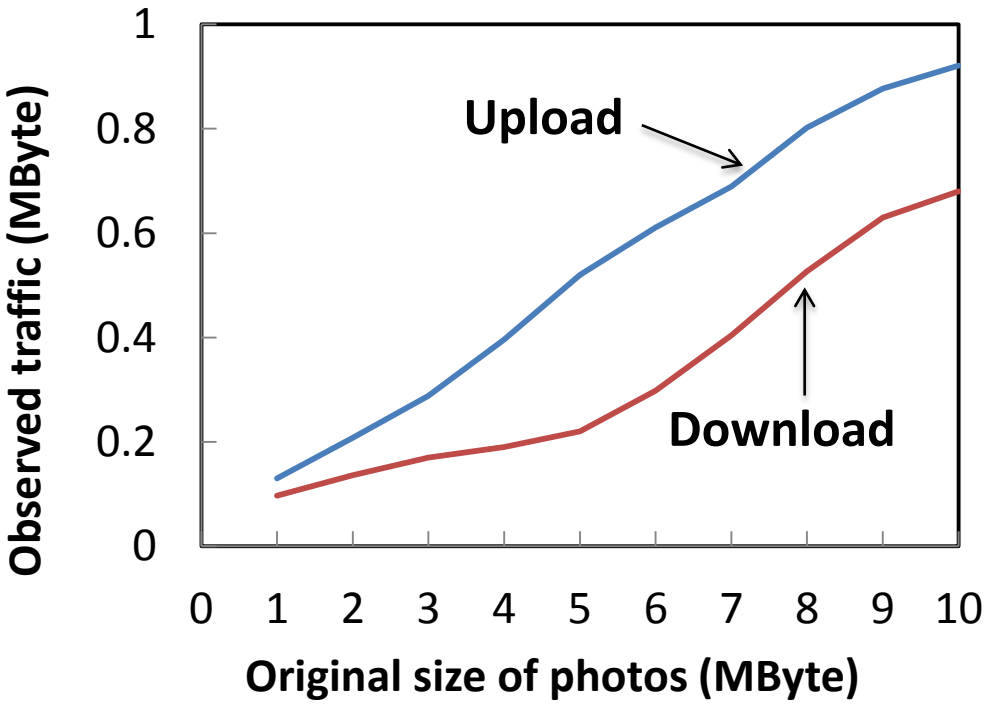
Facebook eco-system



- Hot & Warm photos are distributed by a Content Delivery Network
- Cold Photos are distributed directly from data centres

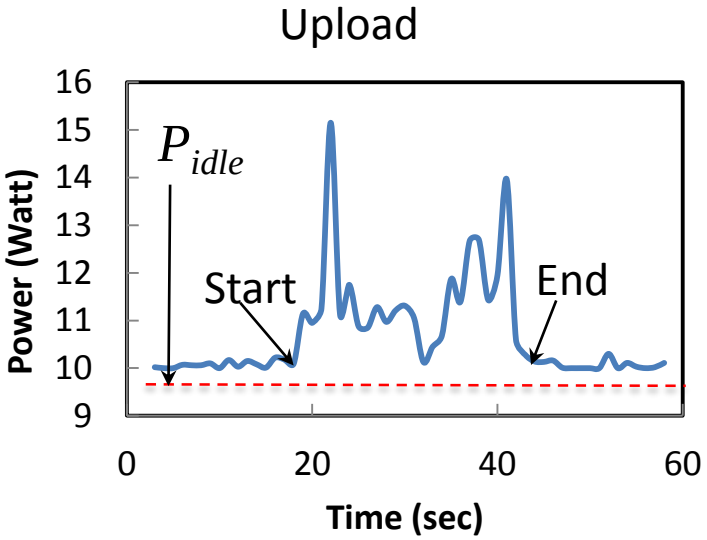
Traffic (measurement)

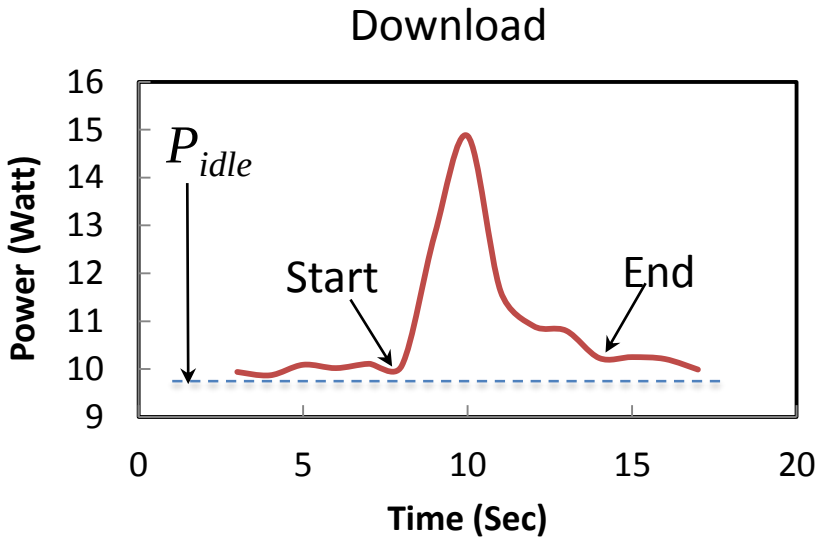
- Packet analyser software utility (Wireshark)
- Further compression on photos in user browsers before uploading to Facebook
- Exchanged Bytes for a 5MB Photo:
  - Laptop (Ethernet, WiFi)
    - Upload = 500KB
    - Download = 200KB
  - Smartphone (4G, WiFi)
    - Upload = 1.1 MB
    - Download = 120K



Energy: user device

- Direct measurement : Power-mate (resolution of 10 mW)
- Uploading and downloading same 5 Mbyte photo





5MB photo	Laptop		Mobile Phone	
	Ethernet	WiFi	4G	WiFi
Upload	106 J	114 J	40 J	23 J
Download	23 J	33 J	18 J	8 J

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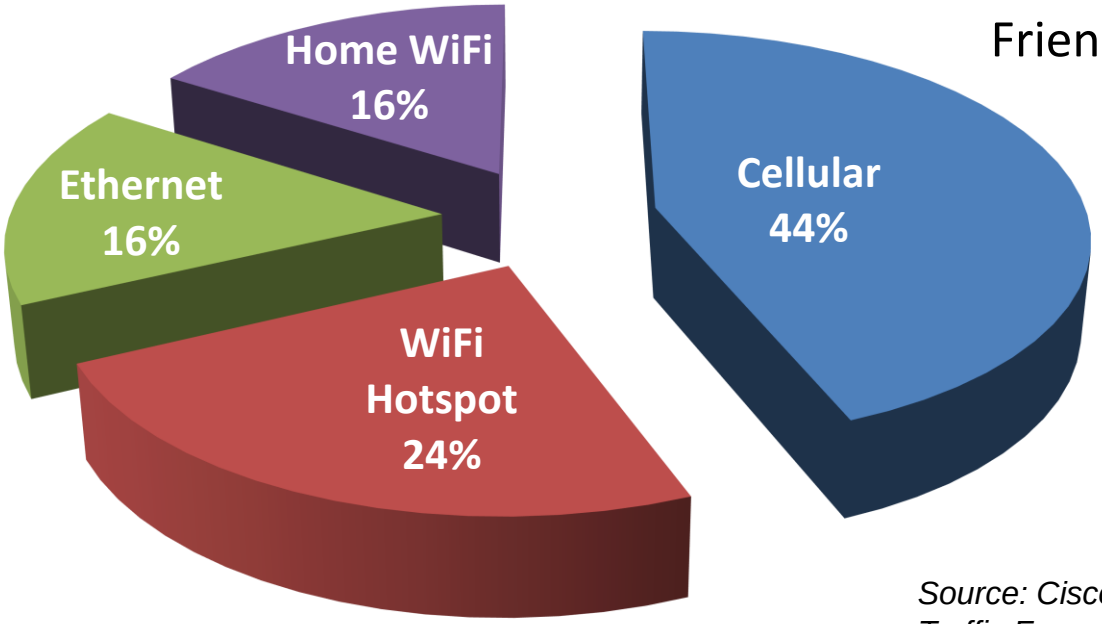
Users' traffic profile

- 350+ million photos upload every day
- Users have 140 friends on average.
- For a new uploaded photo
  - Assume 90% of friends wants to look at the photo (126 friends)



Friend access technologies

Source: Cisco VNI, Global Mobile Data Traffic Forecast Update, 2012–2017

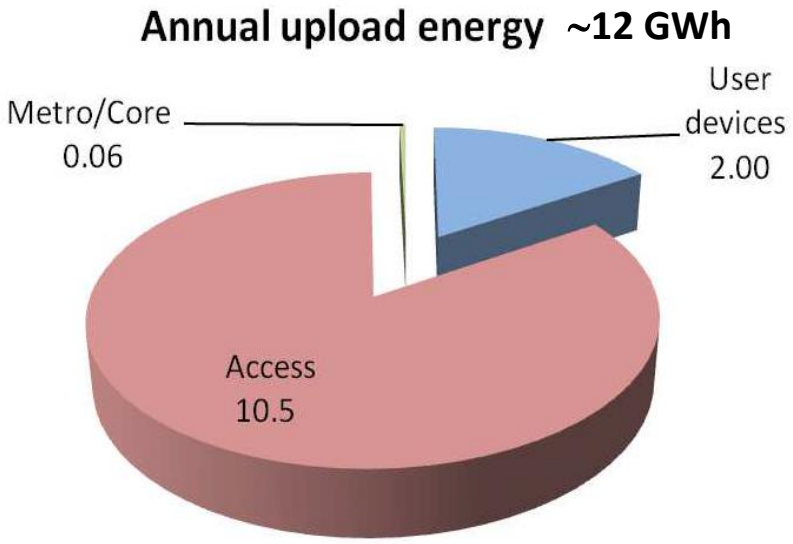
Source: Cisco The zettabyte era, 2012-2017

Sharing online network energy

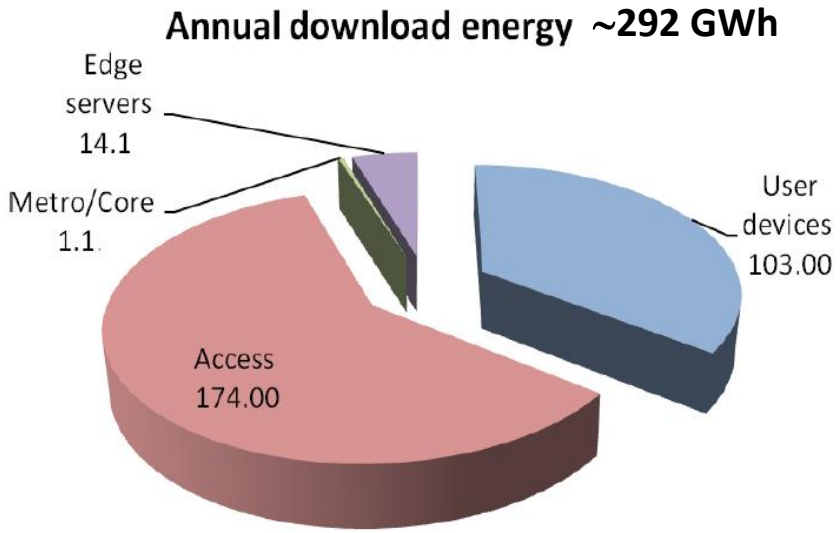
- Facebook 2012 total data centre IT energy : 516 GWh

  (Source: Facebook)

- Total network energy consumption: 304 GWh
- Photo sharing network energy ~ **60%** of FB total data centre IT energy
  - Wireless (4G/LTE) access network is main energy consumption



Upload energy consumption (GWh)



Download energy consumption (GWh)

Case study 4: Cloud storage for “Digital Universe”

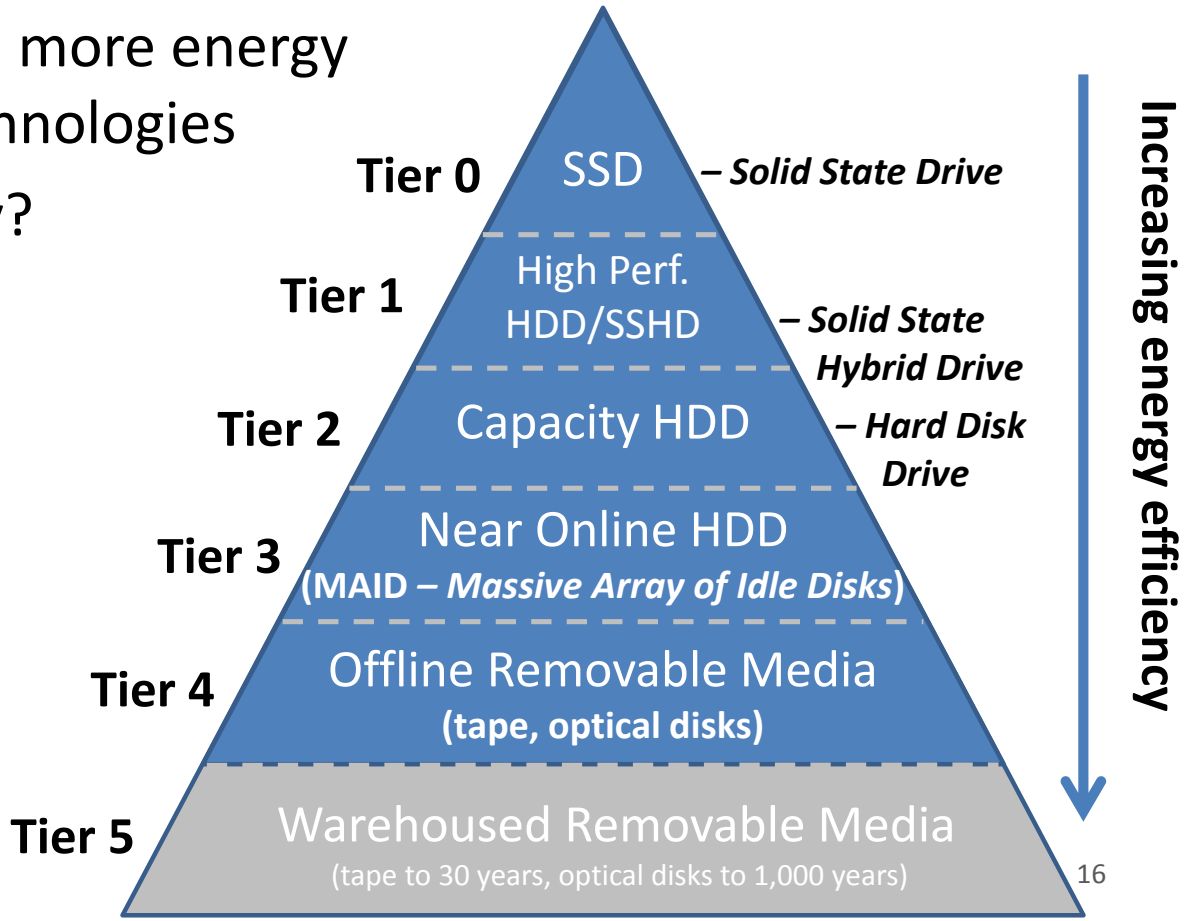
- Digital Universe: all the data created by humankind

http://www.emc.com/leadership/digital-universe/2014iview/executive-summary.htm

How much power to store all this data?

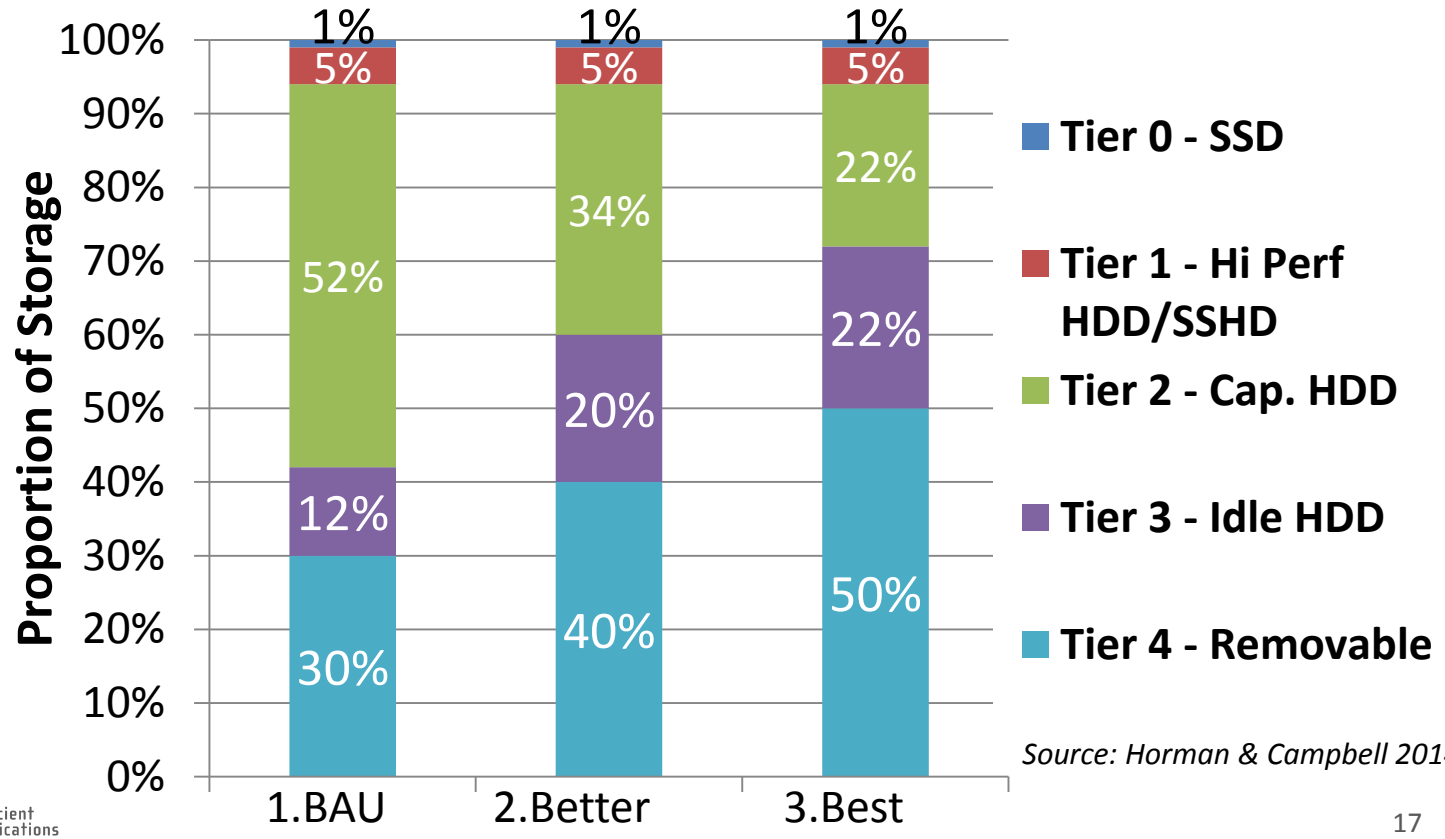
- Today 40% of digital universe is stored in data centres
- Seagate: By 2020 60% will be stored in data centres

  Source: Seagate 2014
- Expect move toward more energy efficient storage technologies
- Will this save energy?



Data storage in 2020

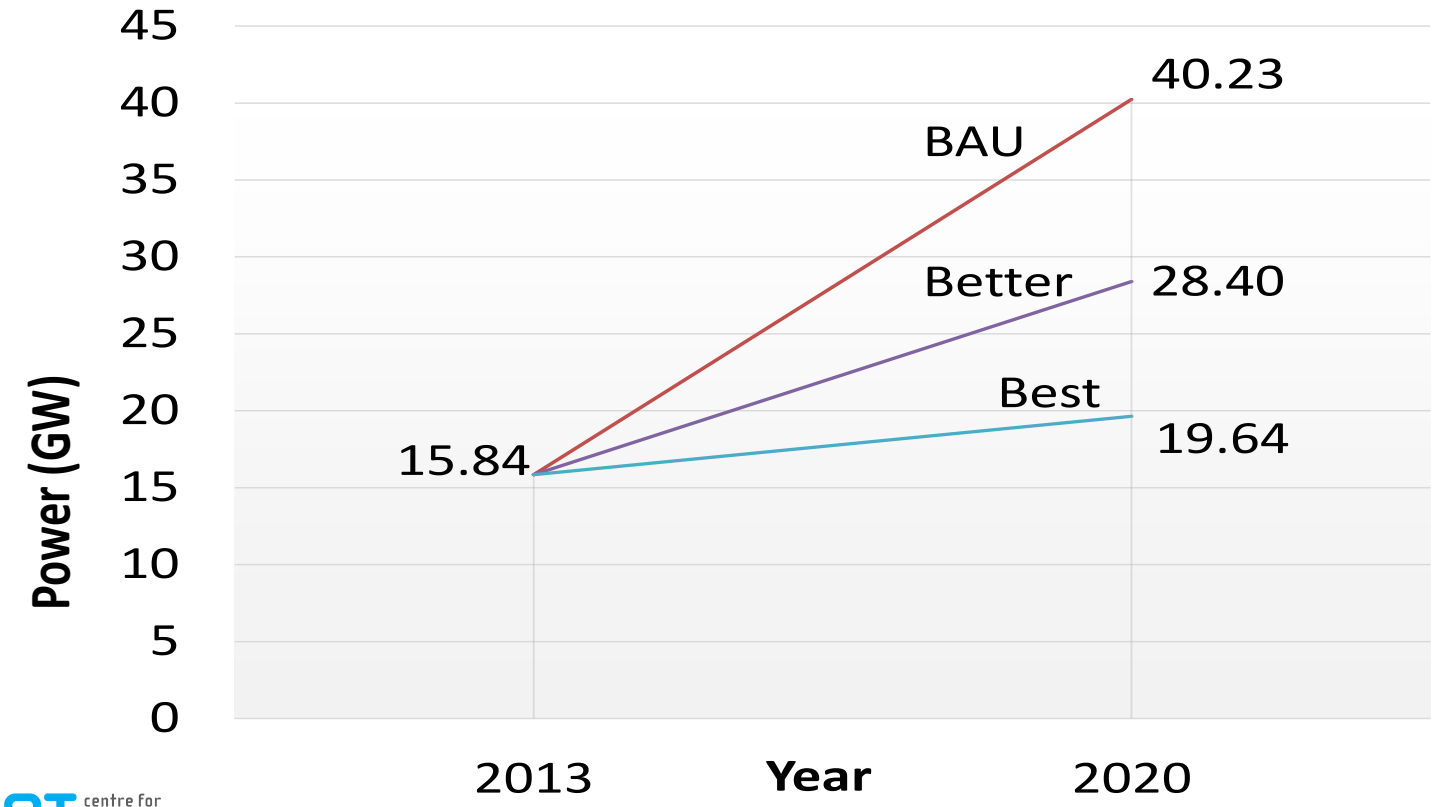
- Consider three scenarios for 2020:
  1. Same storage Tiers as 2013 (BAU)
  2. Better use of lower power storage Tiers
  3. Best likely use of storage Tiers



Source: Horman & Campbell 2014

2020 Digital Universe data storage power

- Without a significant transition to lower power storage data storage power will almost triple
- Need to re-think data retention policies



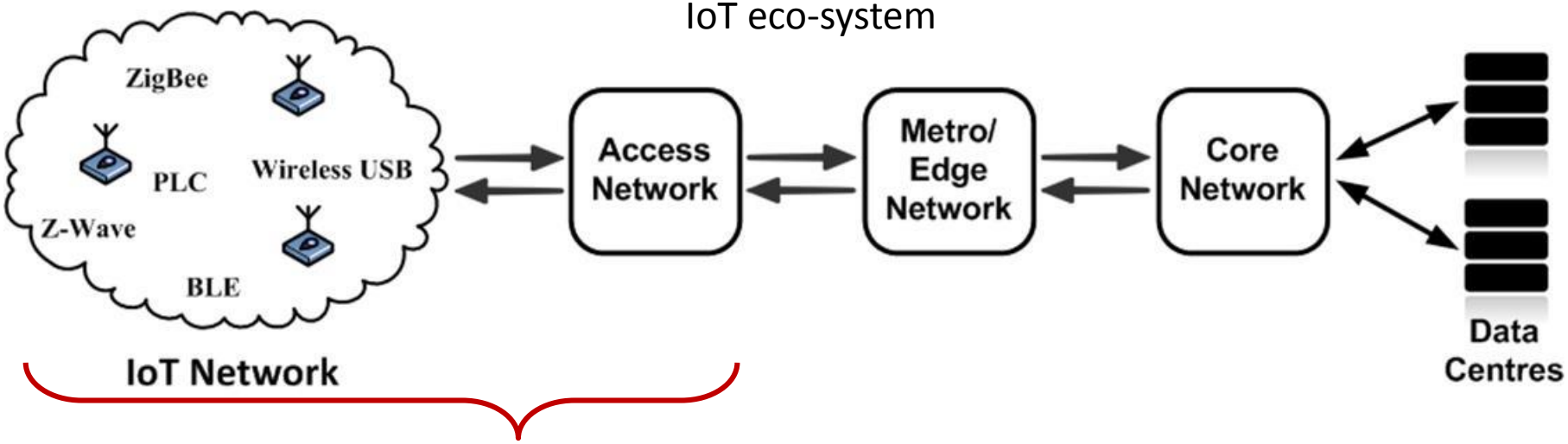
Source: Horman & Campbell 2014

Case study 5: Internet of Things (IoT)

- IoT forecasts
  - 212 Billion connectable things by 2020 *IDC, 2014*
  - 4.6 Petabyte /month in Global M2M traffic by 2019
  - Data increasing at 71% increase per year *Cisco VNI, 2015*
- Mainly small IPv6 packets
- Increasingly sophisticated “things”

Gray et al. 2015

IoT eco-system



Dominant power consumption

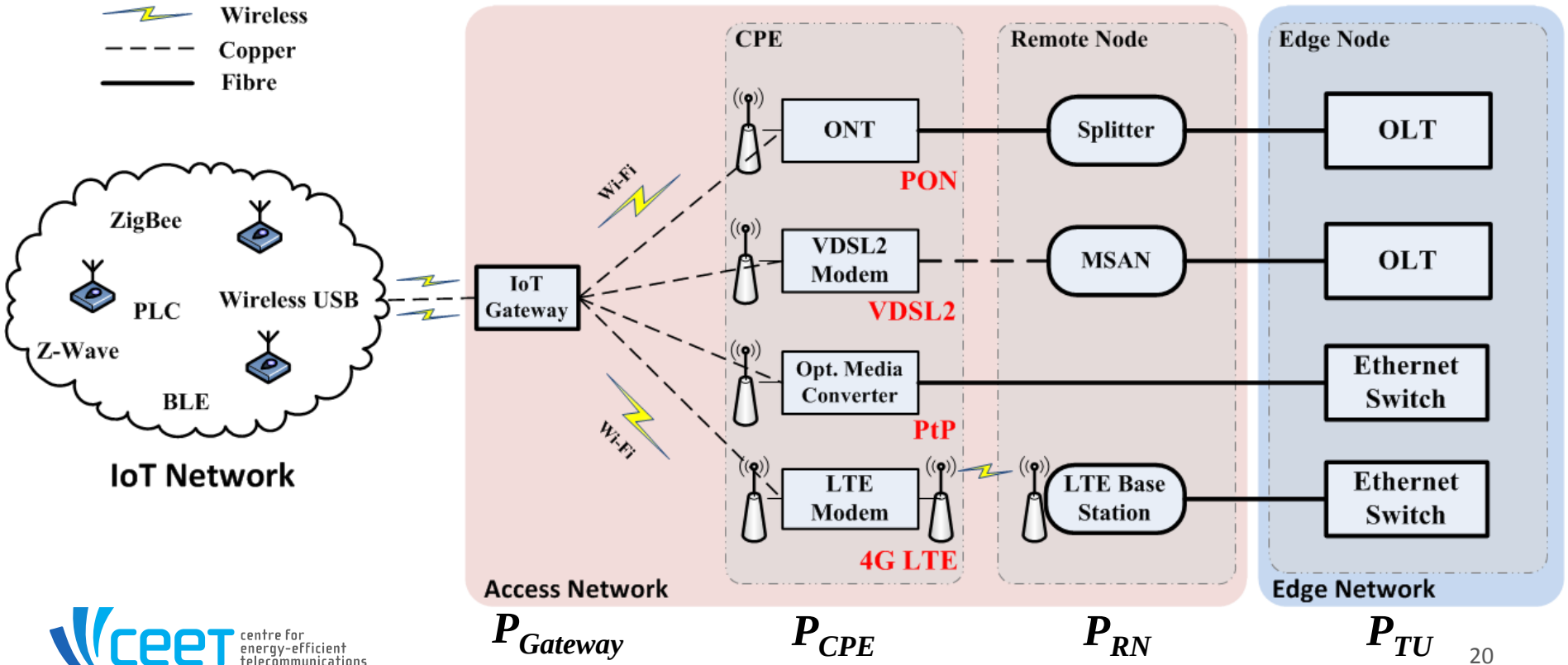
Power Consumption Model

Case Study 5

Gray et al. 2015

- From “thing” to terminal unit (central office)

$$P_{IoT} = P_{Gateway} + P_{CPE} + X_{RN}\frac{P_{RN}}{N_{RN}} + X_{TU}\frac{P_{TU}}{N_{TU}}$$

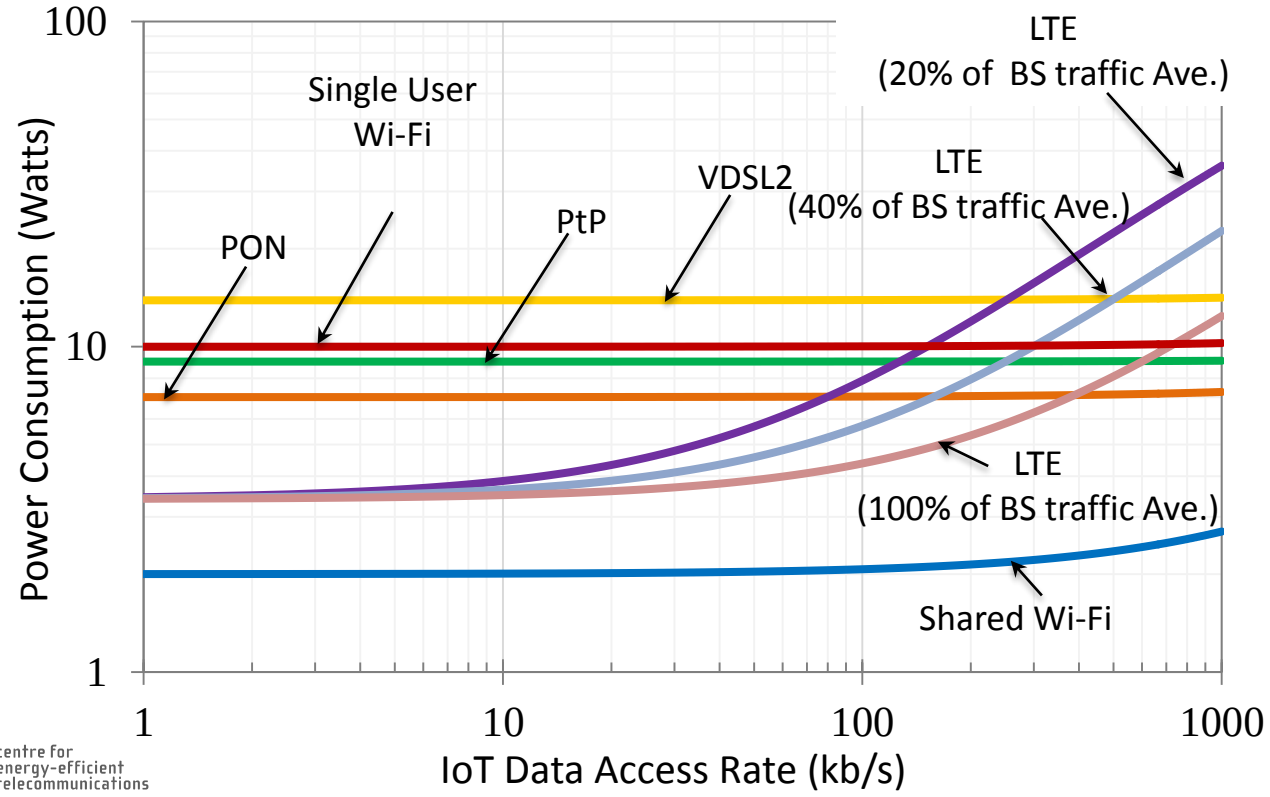


Results

Gray et al. 2015

- VDSL2 is least power-efficient while Shared Wi-Fi (with PON) is most efficient.
- LTE is mostly efficient for bitrates below 75 kb/s but least efficient above ~250 kb/s

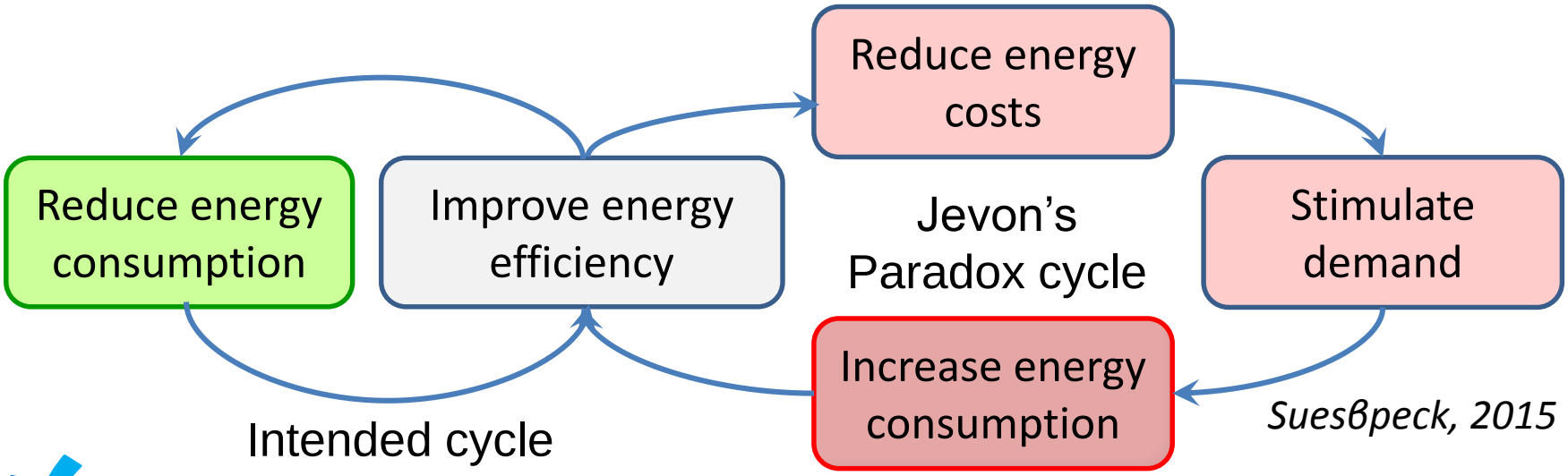
BS = LTE base station



Case study 6: Energy efficiency, CO_2 and "rebound"

- Will the energy efficiency of e-services, of itself, provide for carbon footprint abatement?

- "Jevon's paradox" (Rebound effect)
  - Improving efficiency will stimulate economic activity & increase power consumption



Australia's National Broadband Network

- Nationwide broadband network
  - Multiple technologies
  - Covers entire nation
  - Completion date: early 2020's
- Replace hi-CO_2 material services with lo-CO_2 e-services

Access technology	% premises
FTTP: Fibre to the premises	24%
FTTN: Fibre to the node	30%
FTTdp/B: Fibre to the distribution point or building	11%
HFC: Hybrid fibre-coaxial cable	28%
FTTN (remote footprint)	1%
Fixed Wireless	3%
Satellite	3%
Total premises	100%

Source: NBN Co. Strategic Review, *Exhibit 4-2, p. 97.*

Economic model

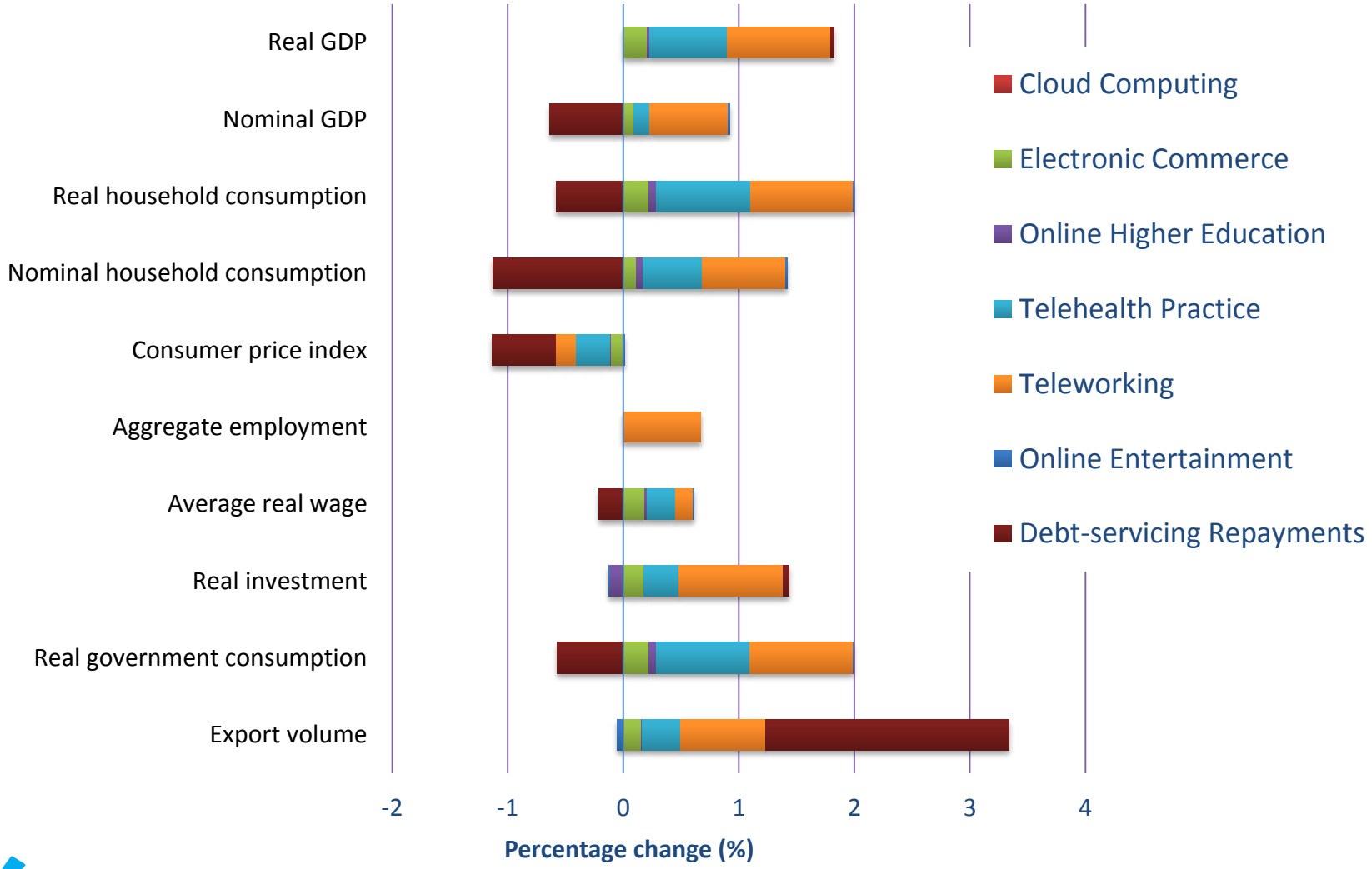
- Use Computable General Equilibrium (CGE) economic model
  - TERM at Centre of Policy Studies: Victoria University, Aust.
- Include added national debt to pay-off NBN construction
- Compare economy relative to “No-NBN” future
  - FTTH in city centres & business areas
  - Primarily DSL with some HFC elsewhere
- Two data rate scenarios

Scenario	Down stream	Up stream
Modest data rate	> 12Mbps entertainment, < 2.5Mbps rest	< 5Mbps
High data rate	2.5-10 Mbps Higher Ed. &Telehealth, 10-25 Mbps rest	≤ 10 Mbps

Six Broadband Services

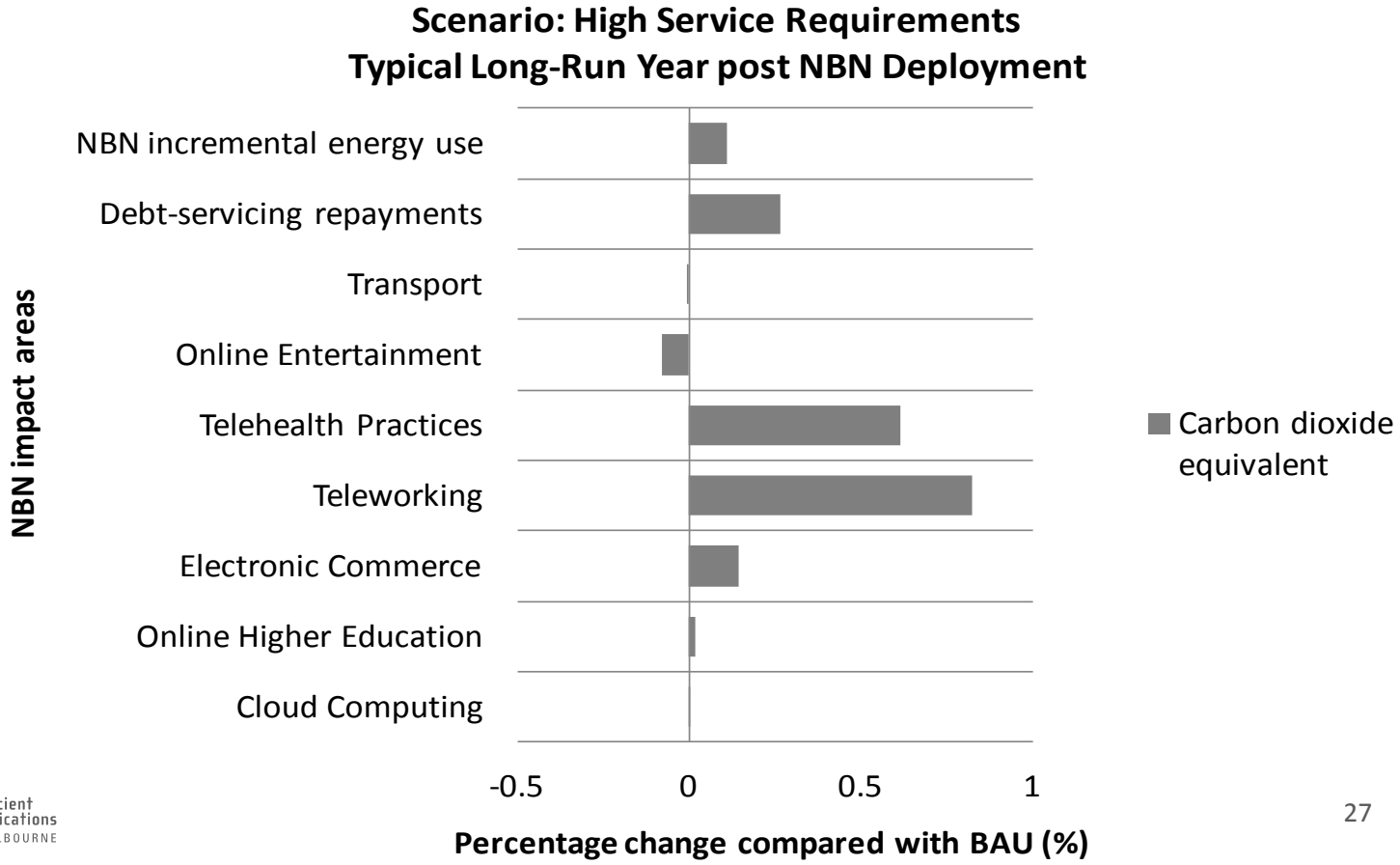
1. **Cloud Computing** for business.
   - Savings depend on the ICT intensity in economy sector.
2. **Electronic Commerce** for business & government.
   - Significant productivity improvements.
3. **Online Higher Education**
   - MOOCs' with some face-to-face supervision.
4. **Telehealth Practice**
   - Telehealth for aged care, teleconsulting & teleconsulting.
   - Broadband-enabled locations in regional areas
5. **Teleworking** improving productivity & enabling greater labour-force participation.
6. **Household entertainment Services**

Long-Term: High Bitrate Requirements



Long-run carbon footprint

- Jevon's Paradox applies: Increased CO_2 due to 2% increase in economic activity
- Need policies to adopt lo-CO_2 practices



National Broadband Networks

- The NBN will boost the Australian economy by about 2% with increase in national welfare
  - Telehealth practice and Teleworking will be most beneficial
- It takes more than better Entertainment to make the NBN economically beneficial
  - But a couple of valuable services using the NBN's increased capabilities will be enough to make the NBN worthwhile
- Ubiquitous broadband alone will not move an economy to lower carbon footprint
  - Need "greening with ICT" policies
    - For example GeSI: SMARTER 2030

Case study 7: Minimising network power

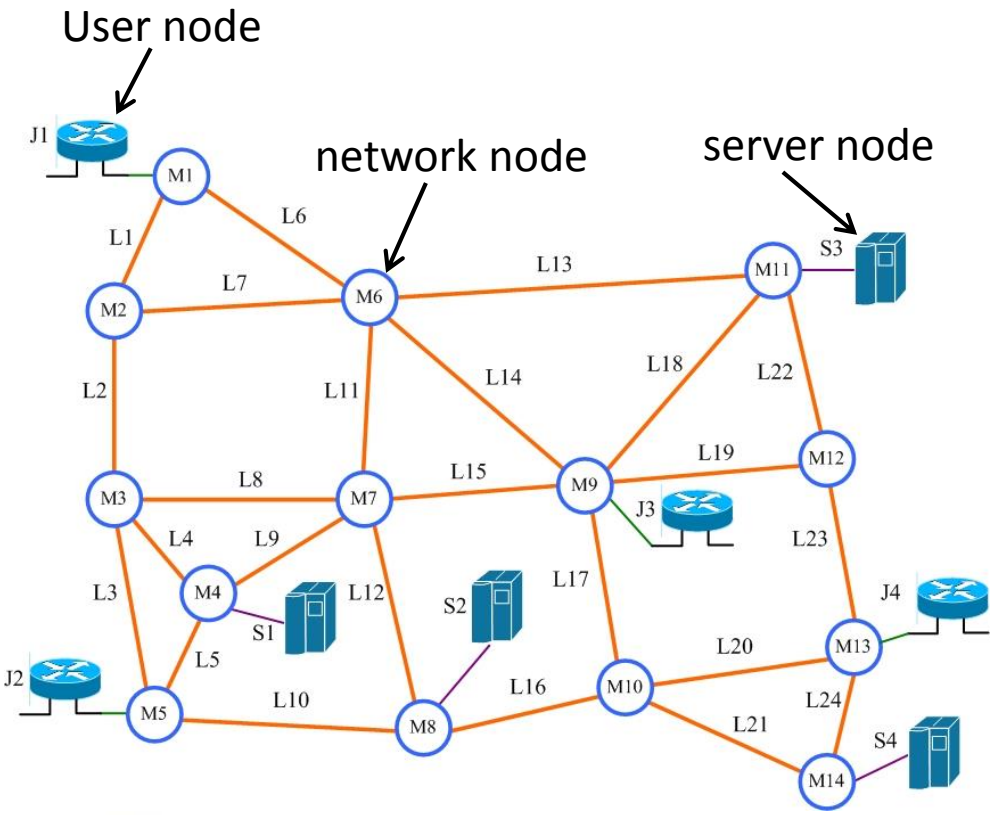
- Does minimising network power require global controller?
  - Enforce optimal solution on all parties
- Real networks have many independent players
  - Service providers, carriers, regulators, users
- Use Game Theory
  - Multiple service providers (players) use a common network
  - Seek Nash Equilibrium for the game
- Each service provider strategy is **weighted balance** of:
  - Minimising their power consumption
  - Balancing the network load
  - Minimising their service delay
- How close is Nash Equilibrium to globally controlled power?

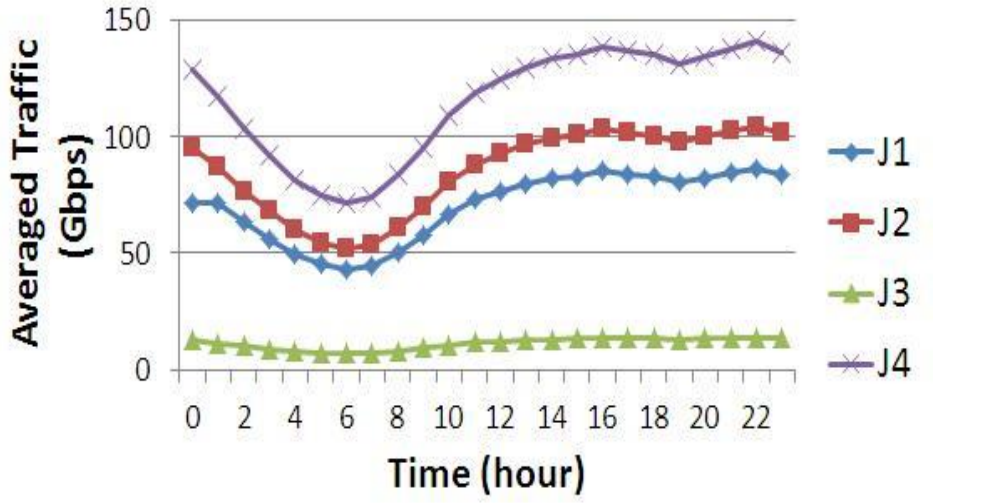
Simulation

- Partial USNET topology
  - 4 user nodes (Input)
  - 4 server nodes (players)
  - 14 network nodes
  - 50 predefined routes between users and server nodes

Users	$J1$	$J2$	$J3$	$J4$
Data centers	$S1, S2, S3, S4$	$S1, S2, S4$	$S1, S2, S3, S4$	$S2, S3, S4$

- Input traffic over a diurnal cycle





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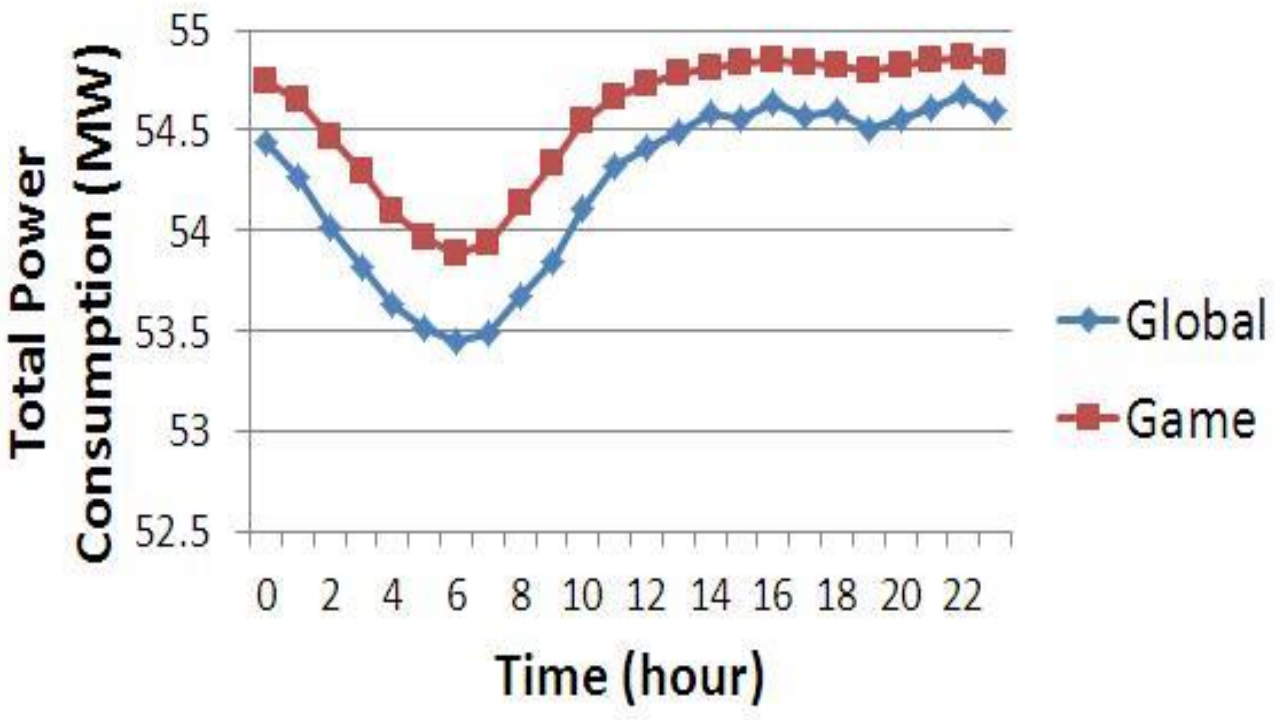
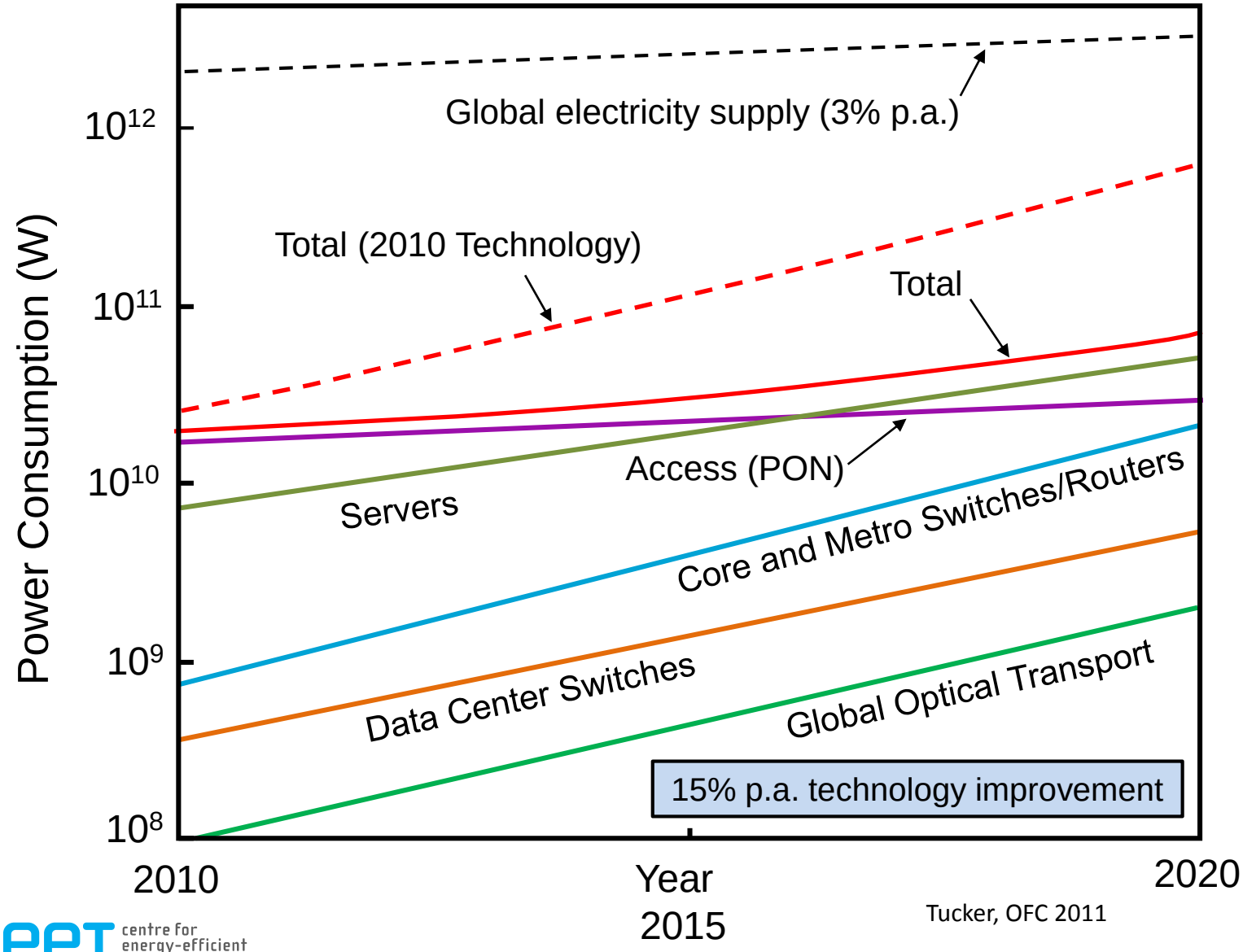
Results

- Provided
  - Players share enough network resources
  - Objectives are relatively aligned
    - Weights for three factors approximately equal
- Power consumption of Nash Equilibrium is close to the global solution
  - Don't need global controller



Power consumption of the global Internet



Tucker, OFC 2011

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GreenTouch

Deliver by 2015 architectures, specifications and solutions and demonstrate key technologies to increase network energy efficiency by a factor 1000 compared to 2010

- Bell Labs initiated global research consortium including
  - Industry
  - Government
  - Academic organizations
- Fundamental research to pre-competitive innovations
- 48 member organizations with 350+ leading scientists
- Recognized by the World Economic Forum as an industry-led best practice toward sustainability
- Finalist for Edison “Collective Disruption” Award 2016
- Launched in May 2010
- Final report on June 2015 (www.greentouch.org)
- Silver medallist “Collective Disruption”: Edison Awards 2016

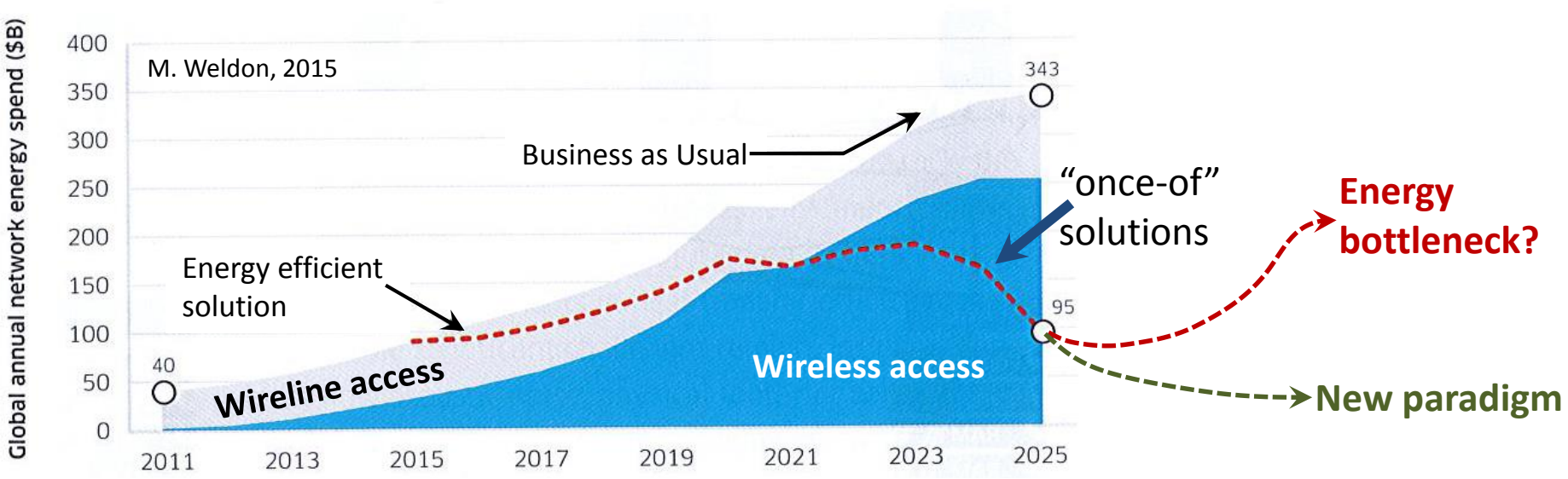
GreenTouch

GreenTouch, 2015	**Efficiency improvement**	**Traffic growth (2010 to 2020)**	**Net energy reduction (2010 to 2020)**
Mobile Access	10,000x	89x	99%
Fixed Access (consumer)	254x	8x	97%
Core network	316x	12x	96%

- Energy efficiency technology roadmap for 2020:
  - Requires all network equipment to be the latest generation
  - Will require all equipment to be upgraded by 2020
  - This is financially challenging over a 5 year period
- However GreenTouch has shown that the technologies are there to secure major improvements

The longer term future

- Most of the energy efficiency gains are “once-of”
  - Can not be used time and again to get continual gains each year
- Expect traffic to continue increasing
- Need a new paradigm to make ICT perpetually sustainable into the future

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Thank you