Energy and the Future Internet

Kerry Hinton

Centre for Energy-Efficient Telecommunications (CEET)
University of Melbourne

Motivation

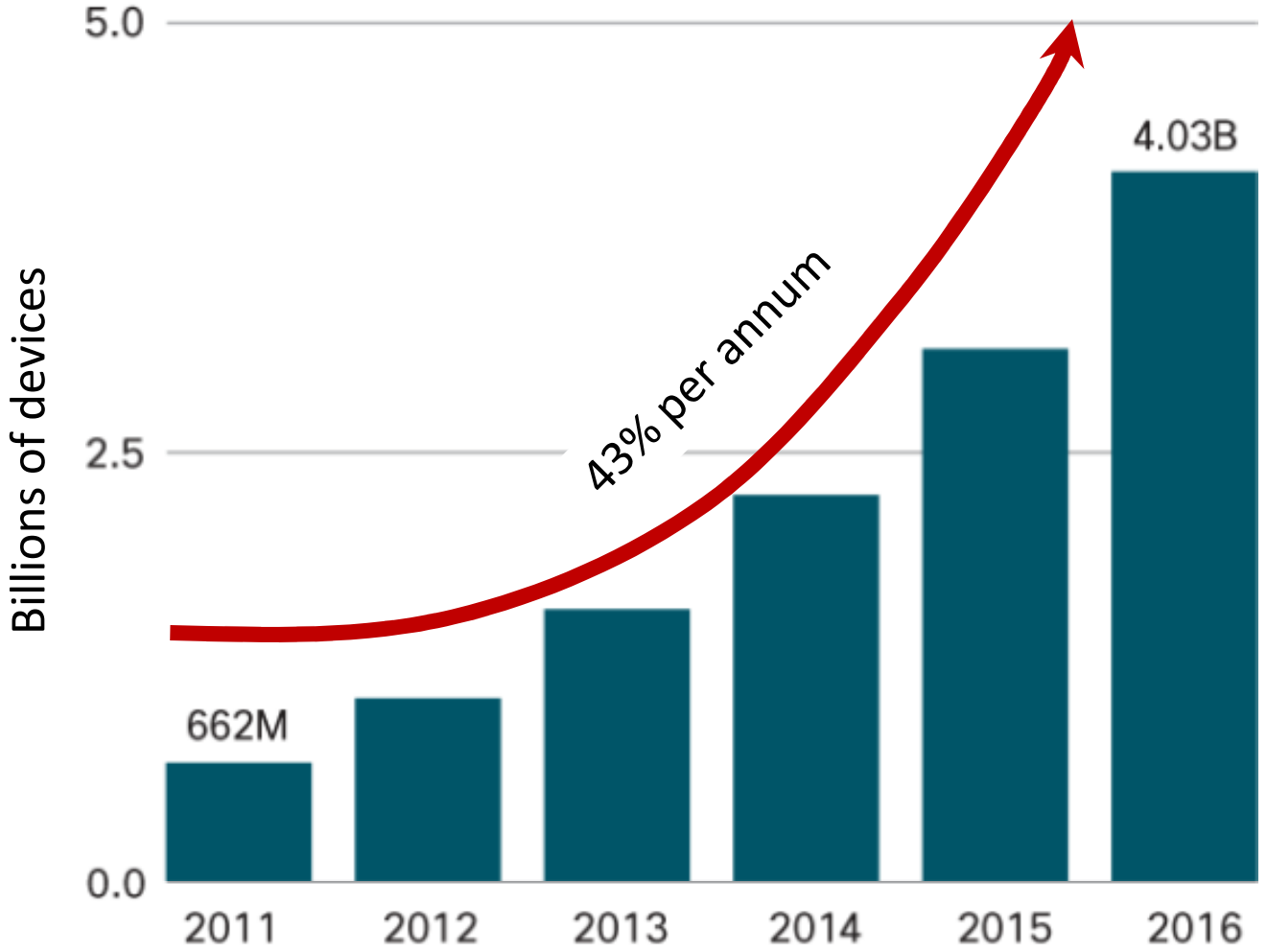
- IPv6 expands address space to order 10^{38} addresses
- IPv6 enables:
  - Multiple addresses per person
    - Internet enabled devices everywhere for everyone
  - Machine-to-machine (M2M) communications
    - In the home, factory, field, car, etc.
  - The Internet of (just about all) Things
- This promises almost endless growth of Internet and e-services
  - Cloud, hi-def video, monitoring, location based, etc.

Motivation

The Internet of Things

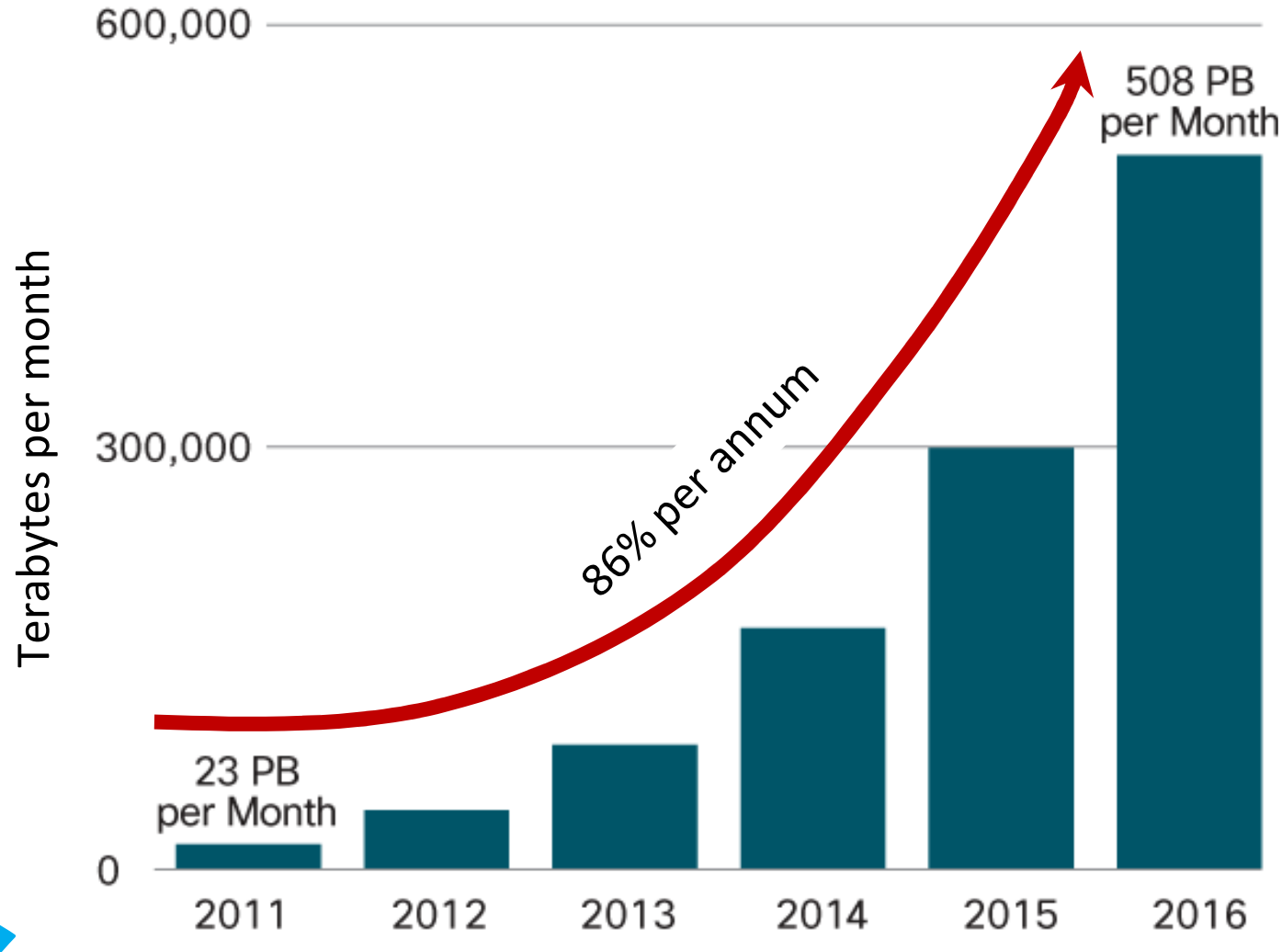
- More users/machines
- More coverage
  - Particularly wireless
- More equipment
- More energy
- Ubiquity of services via wireless
- This talk focuses on energy challenges facing an IPv6 networked world

IPv6 mobile device forecast



Source: Cisco VNI Global Mobile Data Traffic Forecast Update: 2011 - 2016

Machine to machine (M2M) traffic forecast



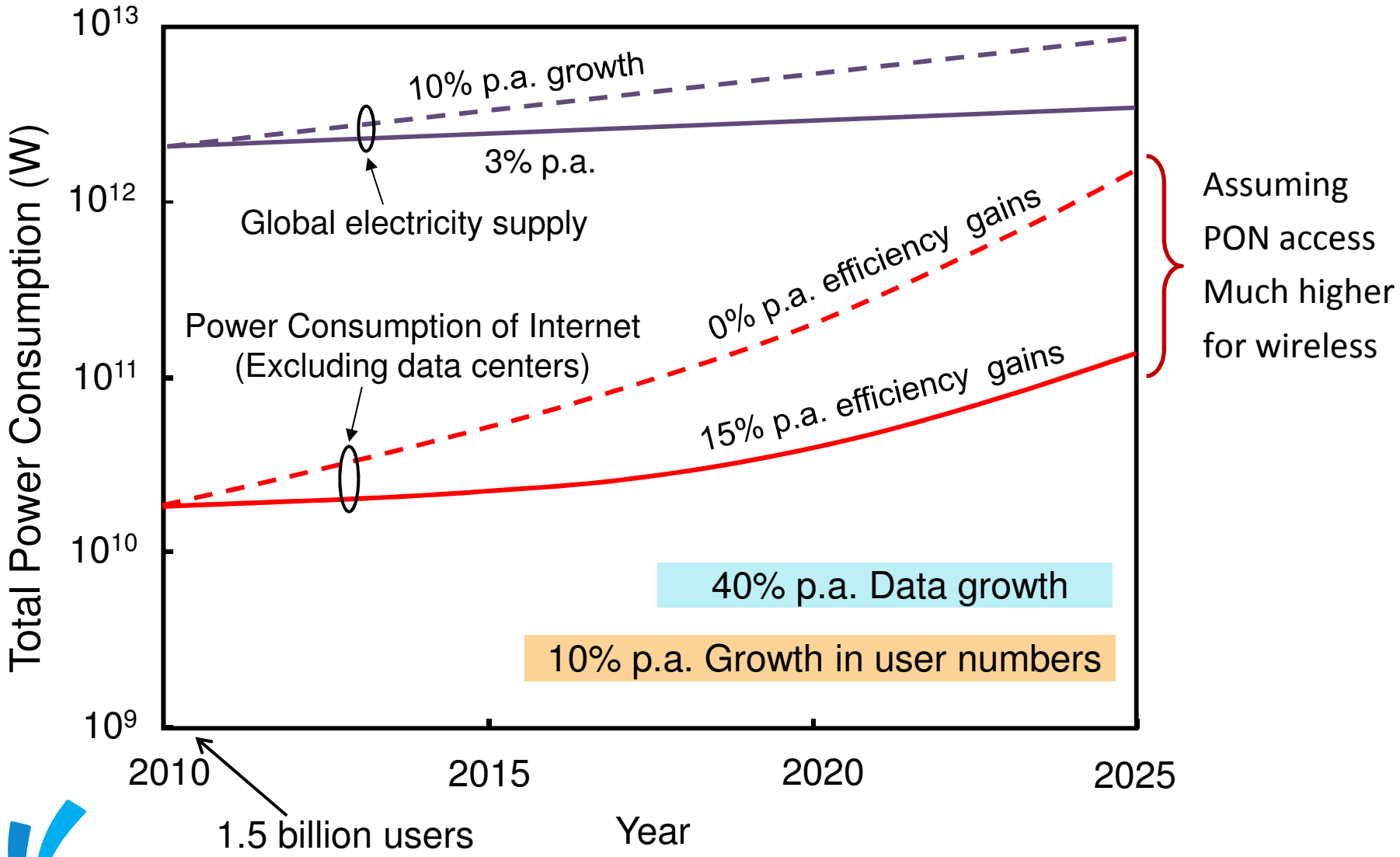
Source: Cisco VNI Global Mobile Data Traffic Forecast Update: 2011 - 2016

M2M/wireless growth forecasts

Expectations are for significant growth in M2M connections

- Infonetics:
  - 428 million embedded M2M connections by 2014
- Analysys Mason
  - 2.1 billion M2M connections by 2020
- Ericsson
  - 50 billion M2M connections by 2020
- Wireless World Research Forum
  - 7 trillion wireless devices by 2020

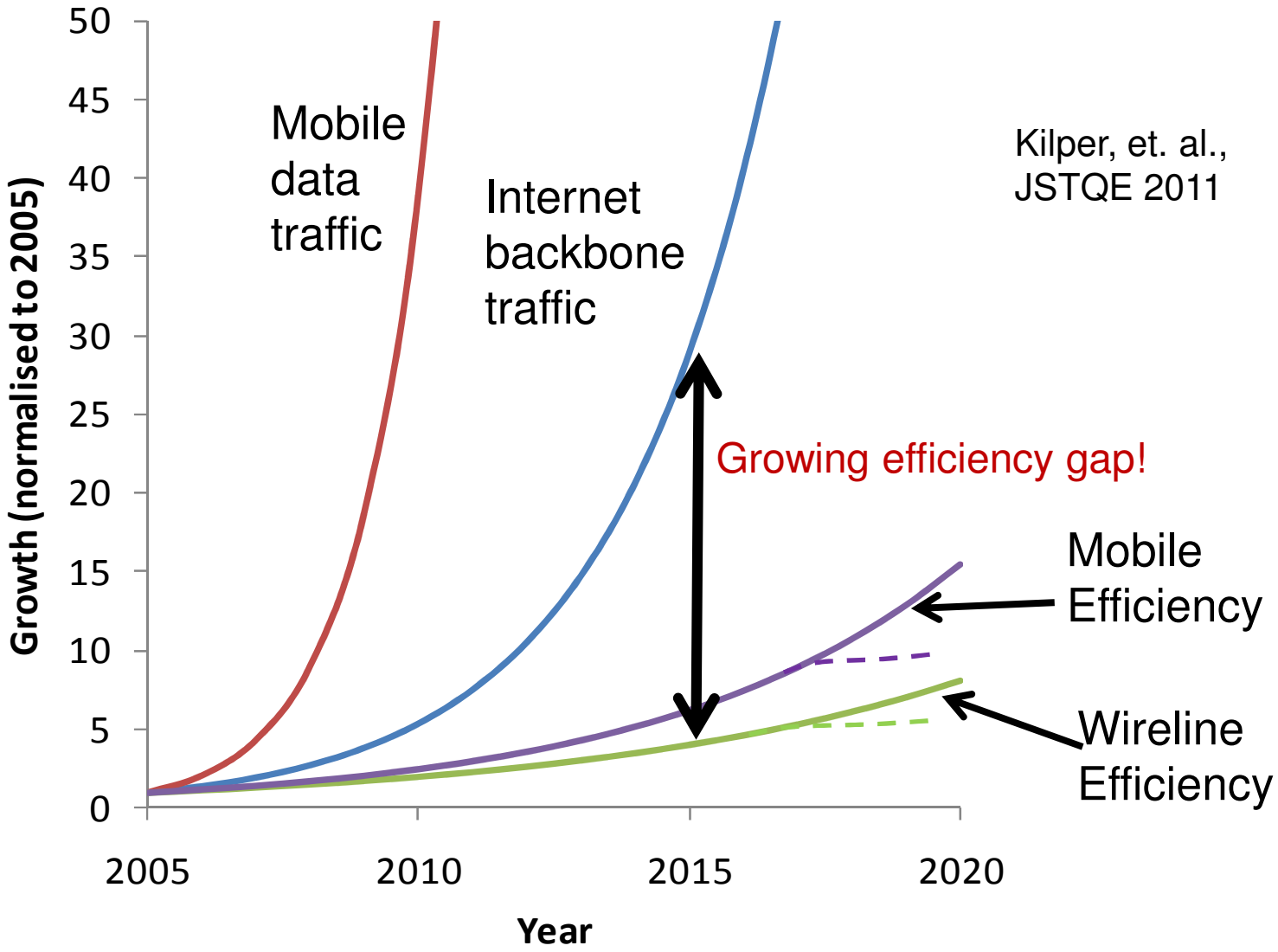
Power consumption of the global Internet



ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Source: R. Tucker, JSTQE 2011

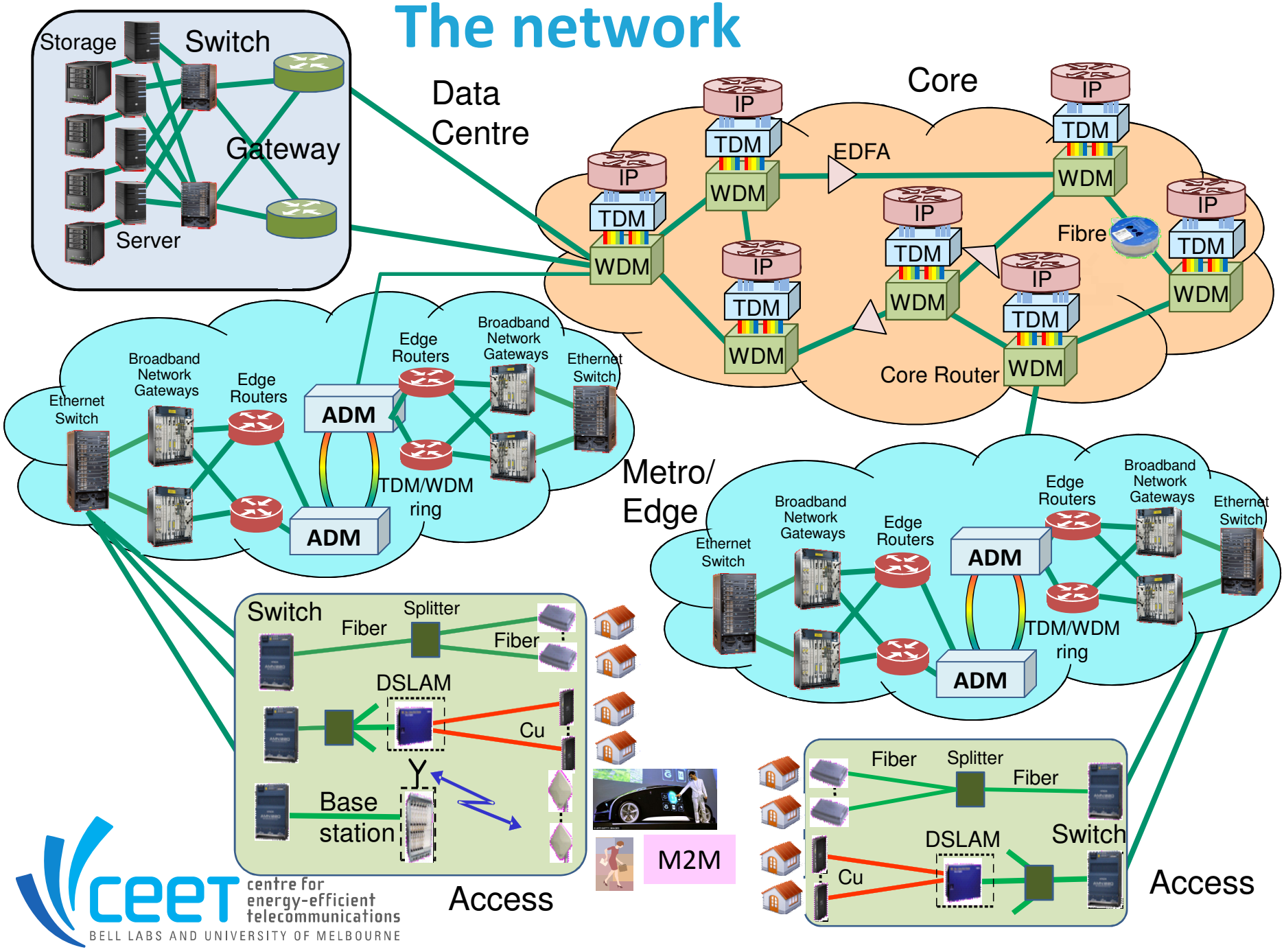
The growing energy efficiency gap



Kilper, et. al., JSTQE 2011

ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

The network



ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Two energy case studies

- Case 1: Wireless access to the cloud
  - 2011 – 2016 global mobile cloud traffic growth ~ 95% pa
    (Cisco: "VNI Global Mobile Data Forecast 2011-2016", 2012)
  - 88% growth from 2009 to 2014
    (Juniper Research: "Mobile Cloud Applications & Services", 2010)
  - Is this growth in mobile cloud services sustainable?
- Case 2: Protocol energy efficiency
  - IPv6 as part of a protocol stack
  - Datagram size and M2M
  - How energy efficient is IPv6?
- Questions rather than answers

ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Public cloud

- Apple iCloud
  - ".. free new cloud services … to automatically and wirelessly store your content in iCloud and automatically and wirelessly push it to all your devices. … all of your devices are wirelessly updated almost instantly."

- Google Drive
  - "Google Drive is everywhere you are – on the web, in your home, at the office and on the go. So wherever you are, your stuff is just...there. Ready to go, ready to share."

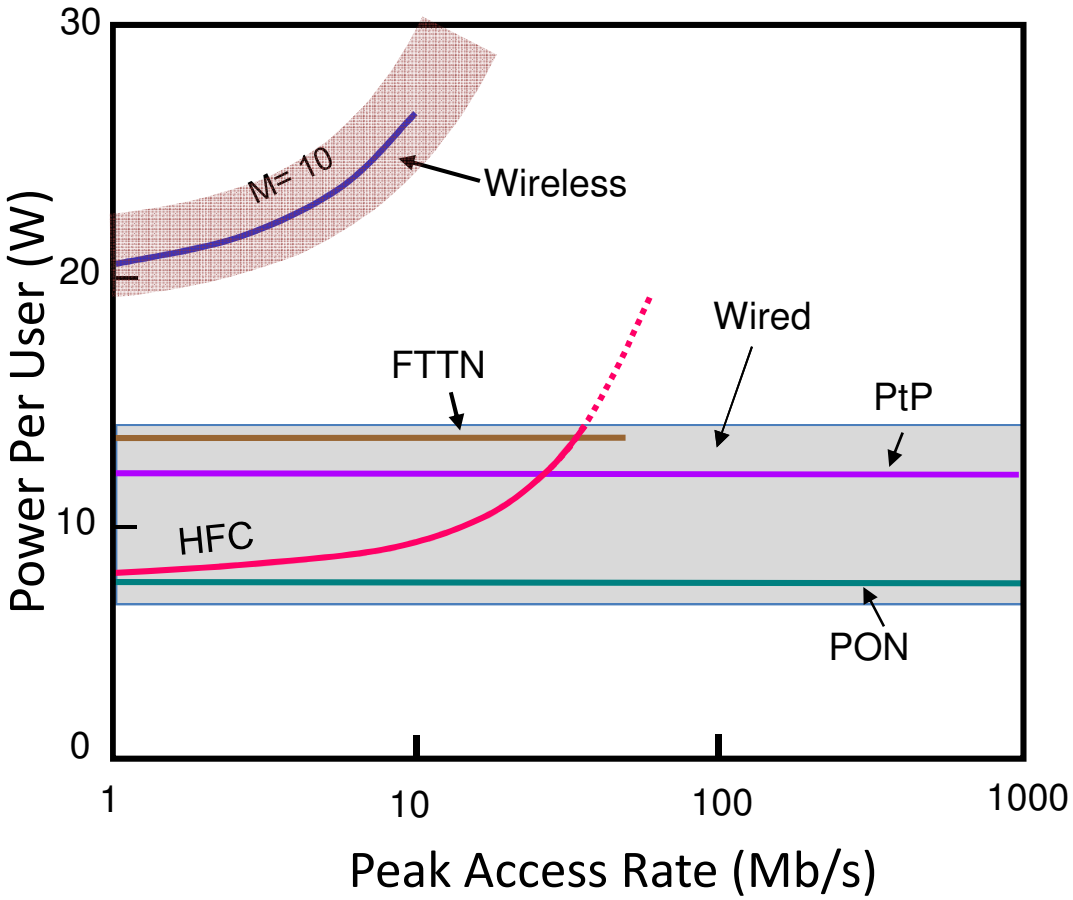
- Microsoft Sky Drive
  - "Store anything on your SkyDrive and it's automatically available from your trusted devices—no syncing or cables needed."

Future cloud services

- "Any where, any time, any service" access
  - Access via wireless
- Users can be scattered around globe
  - Long distance transport of data & commands
    - Public Cloud with many router hops
- Documents and projects kept up-to-date in Cloud
  - High transaction rates
- Simple low power devices & "Things"
  - Processing and storage in the Cloud

Energy efficiency of accessing the cloud

- Mobile access is becoming dominant access technology
  - Any where, any time, any service
- Mobile is least energy efficient
  ~ 25 W/user
  @ 10 Mb/s
- PON is most efficient
  ~ 7 W/ user

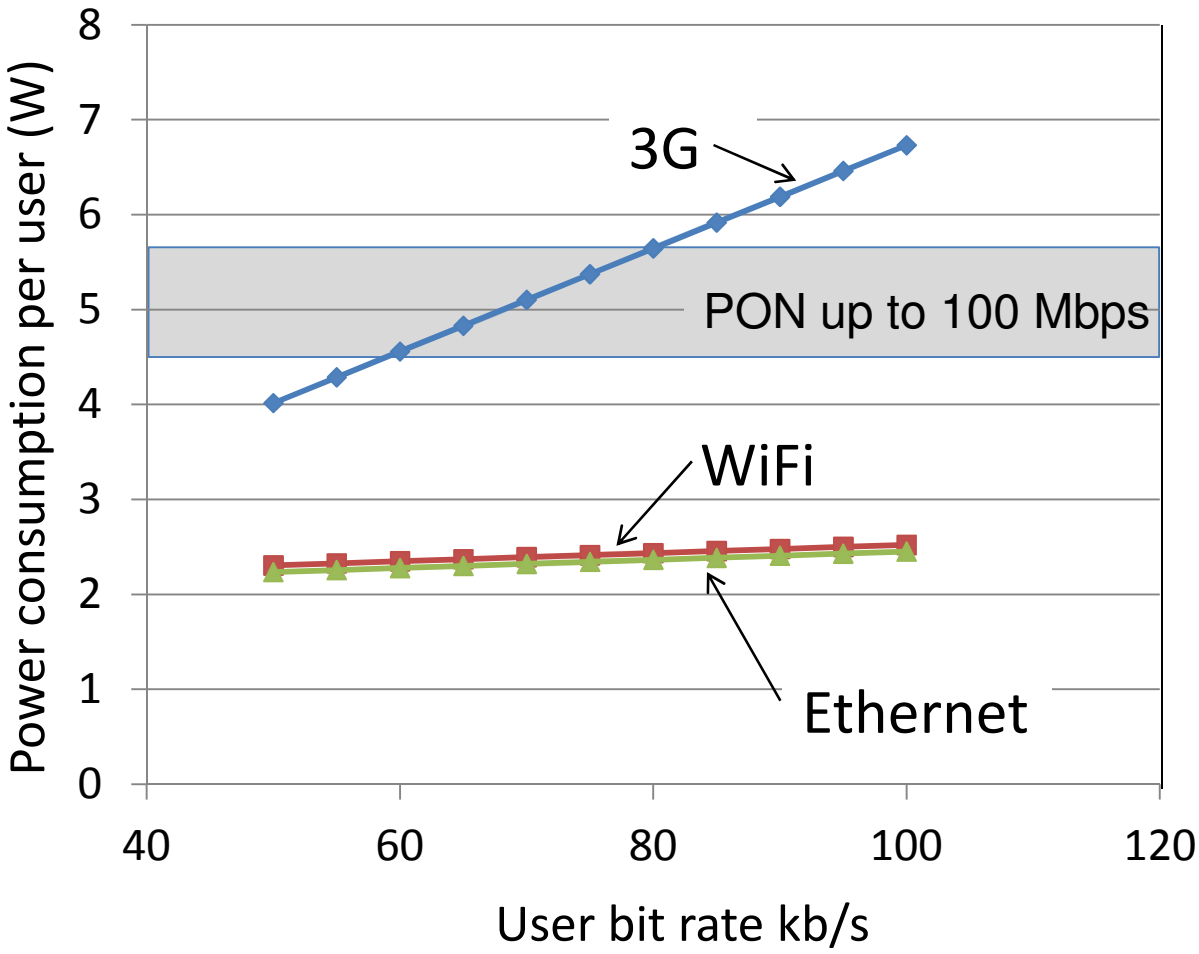


Source: Baliga et al: OFC 2008

Case 1

Power footprint of interactive cloud

- User typing speed ~ 60 b/s ➡ 60 kb/s
  - 1000 x overhead
- Requires more network infrastructure
  - More base stations
  - More power



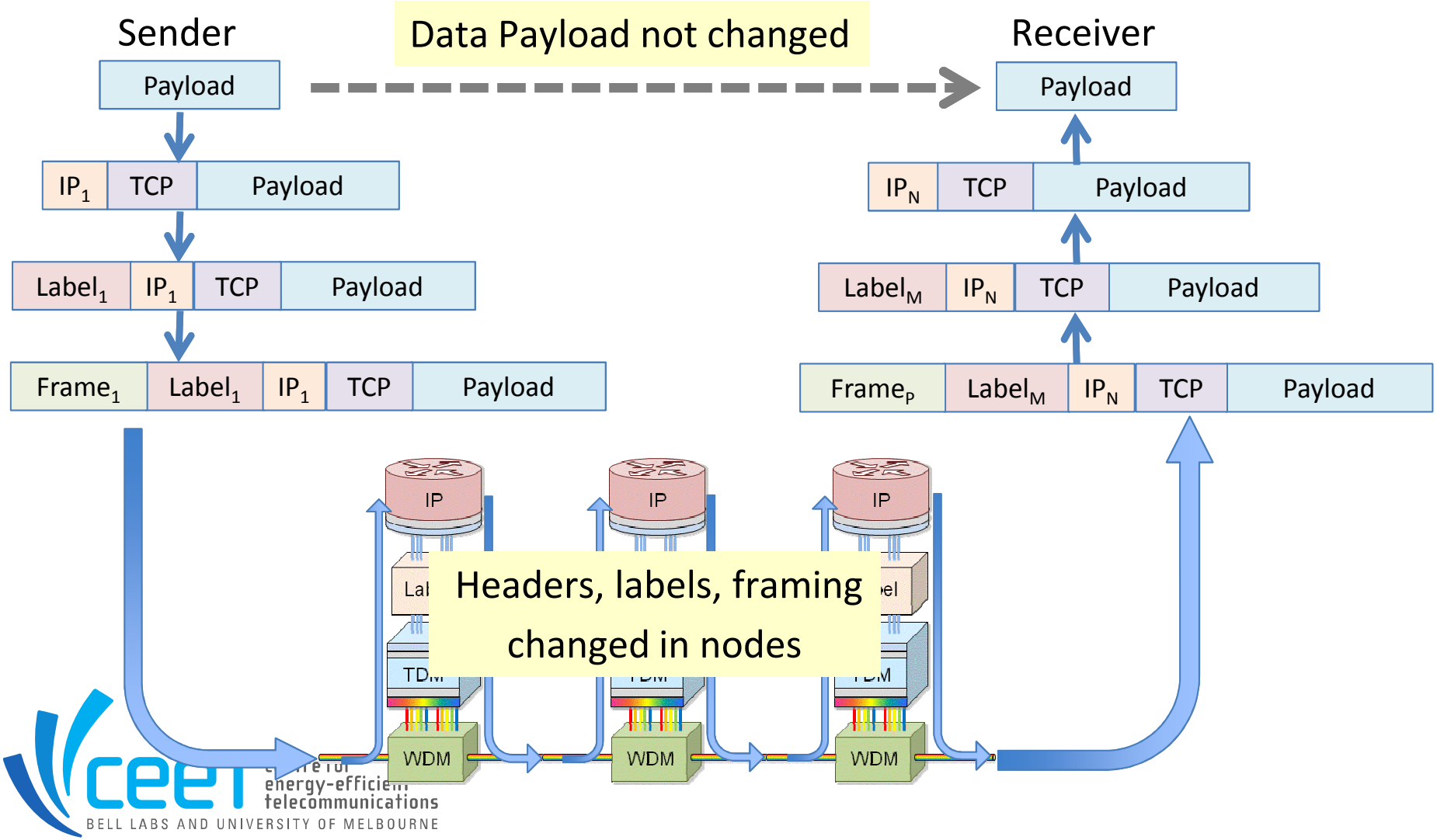
ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

M2M and the Cloud

- Most M2M connections will be via wireless
  - A significant number via 3G/4G
- M2M devices will have minimal processing power
  - Extends battery life
  - Means processing will be in the cloud
    - Results may then be sent back to device
- Multiple hops between device and cloud
- Small traffic from each device but millions/billions of devices
- This will present a major power consumption challenge

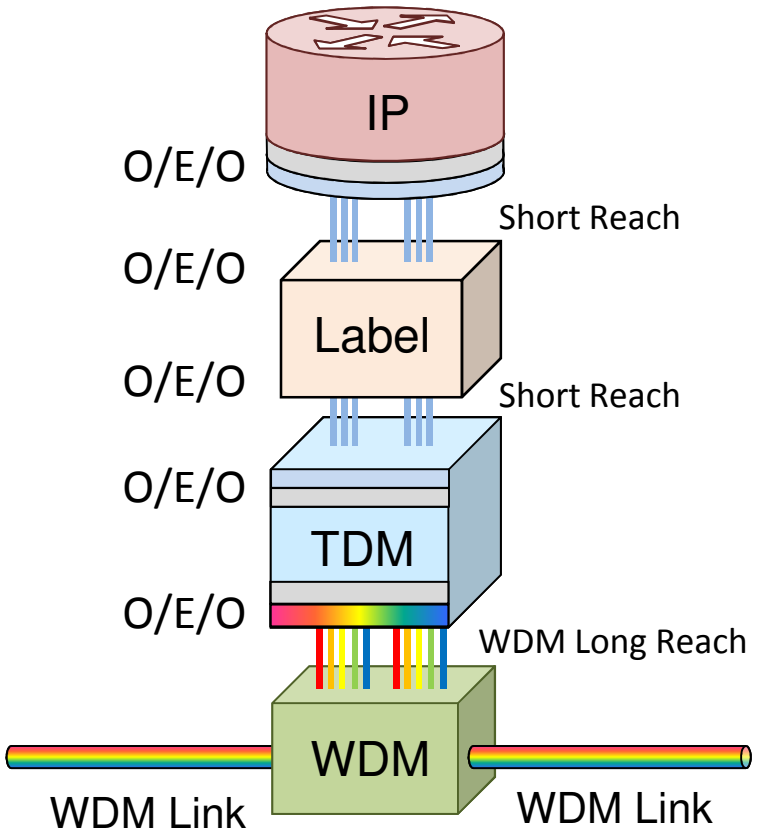
Multi-layer protocols

- Communicate customer data from sender to receiver



Multi-layer protocol node

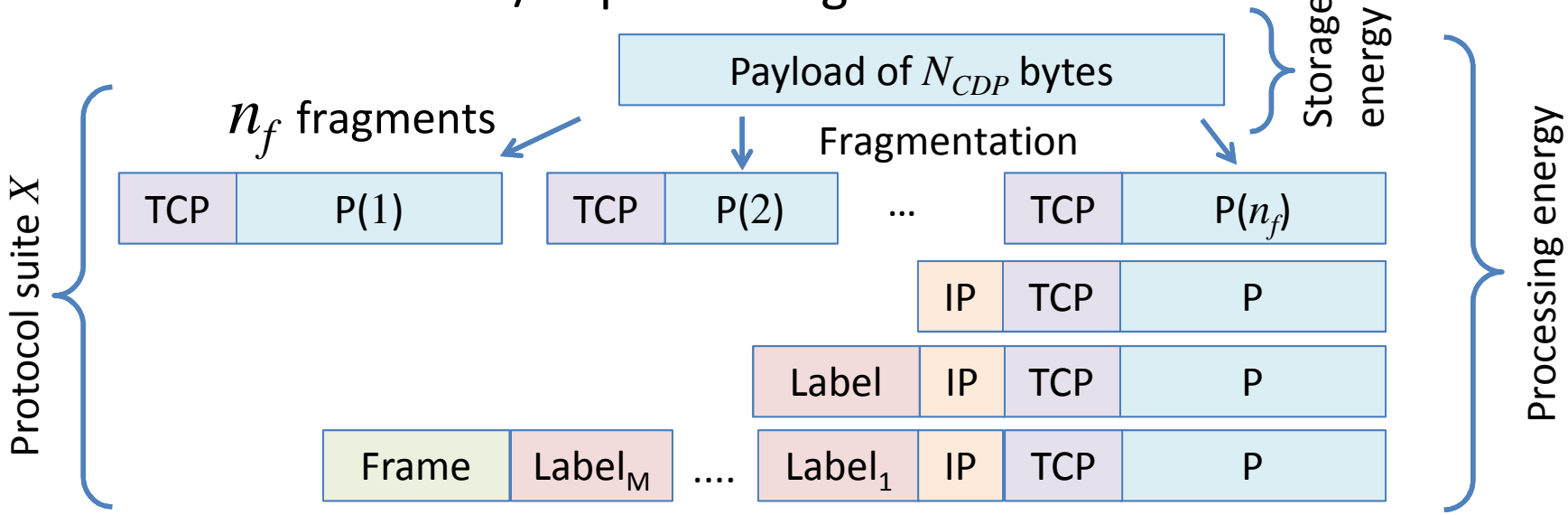
- Multi-layer protocol suites:
  - IP/OTN/WDM, IP/Ethernet, IP/PPP/SDH/WDM, IP/MPLS/SDH/WDM, etc
- Total energy per Payload includes
  - Storage/buffering
  - Switching
  - Layer overhead processing
  - Payload processing
  - Inter-connect power
- O/E/O short reach between layer boxes



Case 2

Energy efficiency of multi-layer protocol

- Payload (P) is the basic unit
  - May be fragmented
  - Minimum Payload energy is storage in IP router
- More overhead and/or processing is less efficient



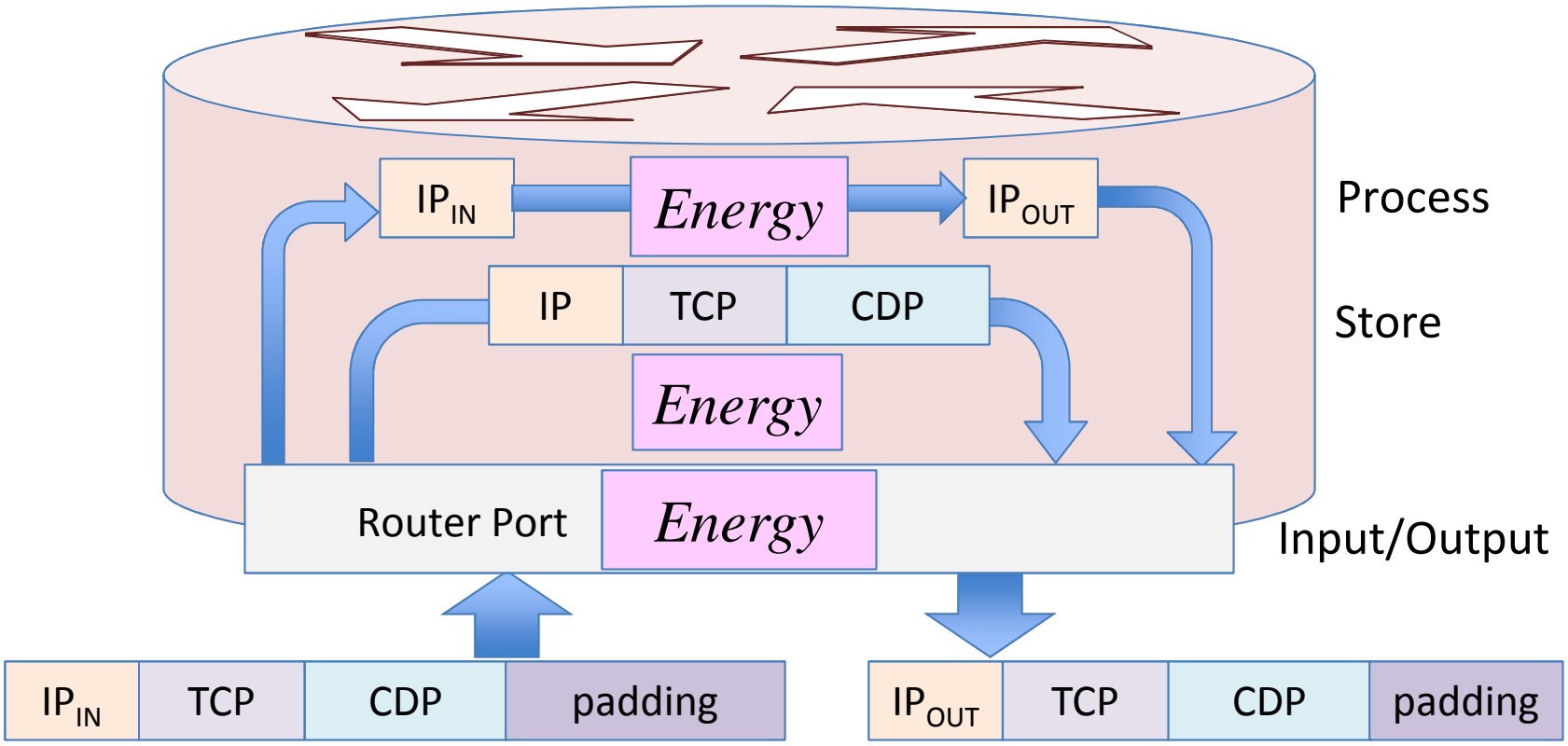
Energy Efficiency = $\frac{\text{Ave. Payload storage energy in IP router}}{\text{Ave. total energy per Payload for protocol in node}}$

Case 2

"Store & Forward" protocols

Fragment energy = I/O of packet and padding + Packet storage + Header processing

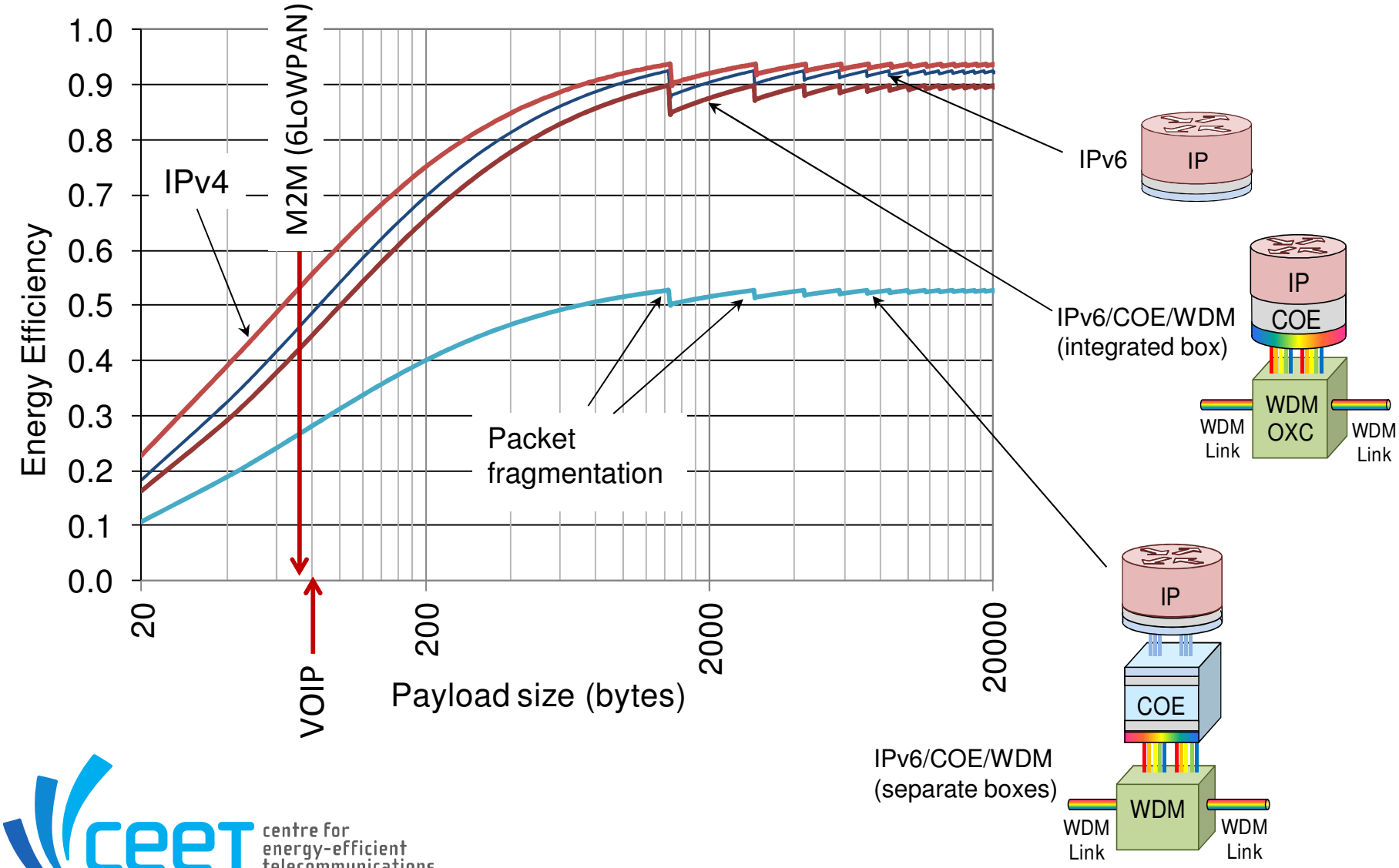
Total Payload energy = n_f x Fragment energy



ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Case 2

Multi-layer protocol energy efficiencies



ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Conclusions

- IPv6 offers networking everything
- Wireless makes this very convenient
  - Anywhere access
  - Everything access
    - The Internet of Things
- Connecting “Things” to the Internet requires power
  - Wireless access is the least energy efficient
- Things use small packets
  - Much more energy consumed in the protocols than in the payload
- The current energy efficiency improvement rate is not fast enough

ceet centre for energy-efficient telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE

Thank you


ceet
centre for
energy-efficient
telecommunications
BELL LABS AND UNIVERSITY OF MELBOURNE