Core Switching and Routing Working Group

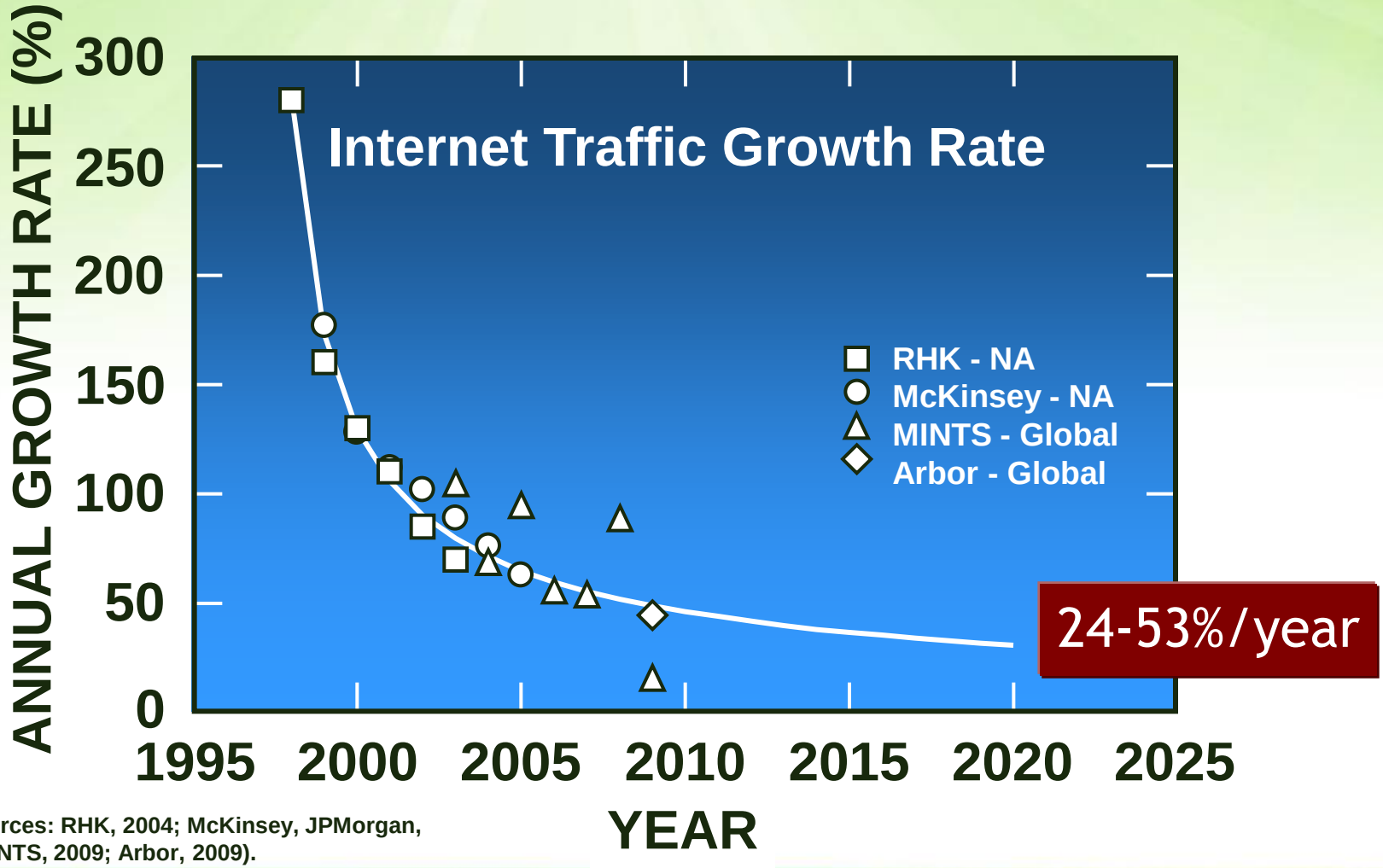
Overview, Research Targets and Challenges

Thierry E. Klein
Chair, Core Switching and Routing Working Group
GreenTouch Open Forum
November 17th, 2011

Overview

- Core Switching and Routing Working Group
  - Technology Limitations
  - Energy Efficiency Challenges
  - Focus Statement
  - Membership
- Energy Efficiency Improvement Opportunity
- Research Targets
- Key Research Projects and Activities

Past and Anticipated Internet Growth



SKK, 2010 (Sources: RHK, 2004; McKinsey, JPMorgan, AT&T, 2001; MINTS, 2009; Arbor, 2009).

Courtesy of Steve Korotky

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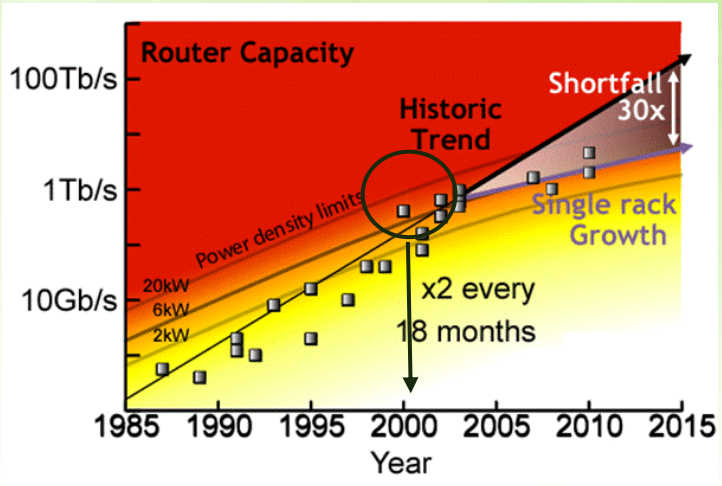
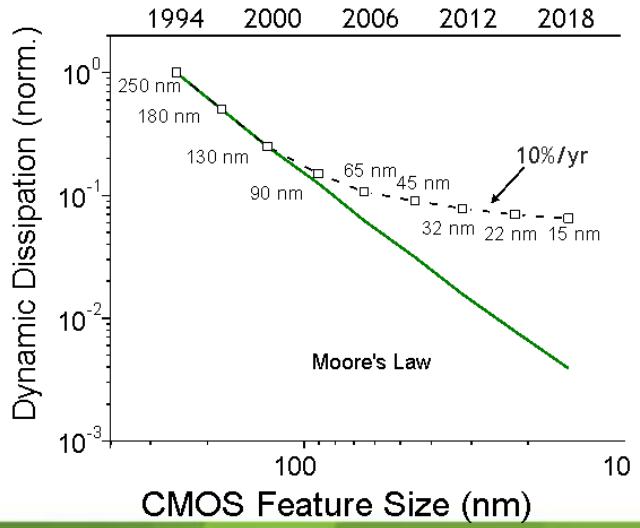
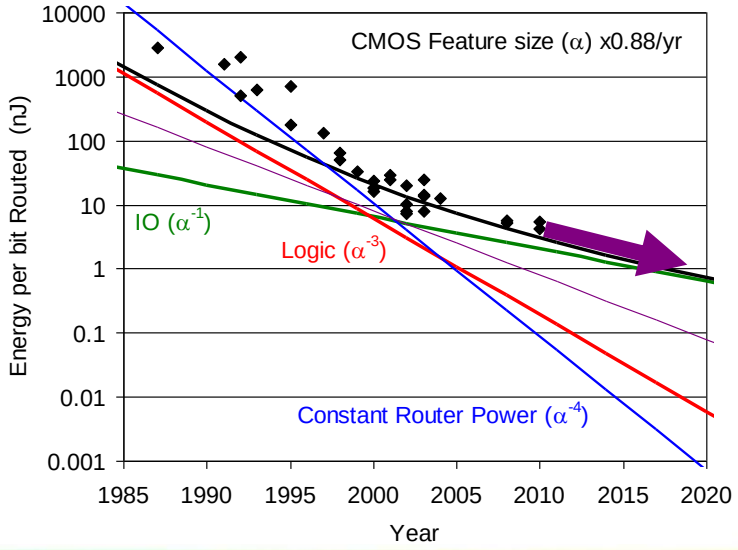
Traffic Growth and Technology Slow-Down

- Traffic doubling every 2 years
  - 40% per year
  - 30x in 10 years
  - 1000x in 20 years
- Slow-down in technology
  - Network energy efficiency increasing 10-15% per year
- **Leading to an energy gap**







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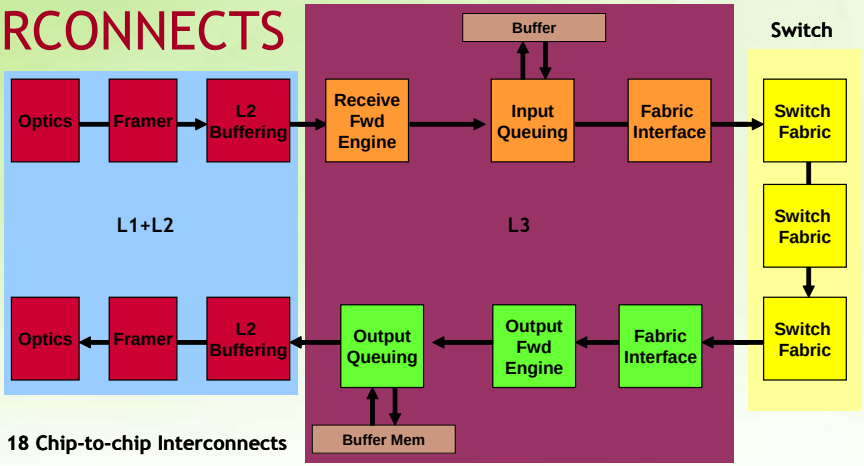
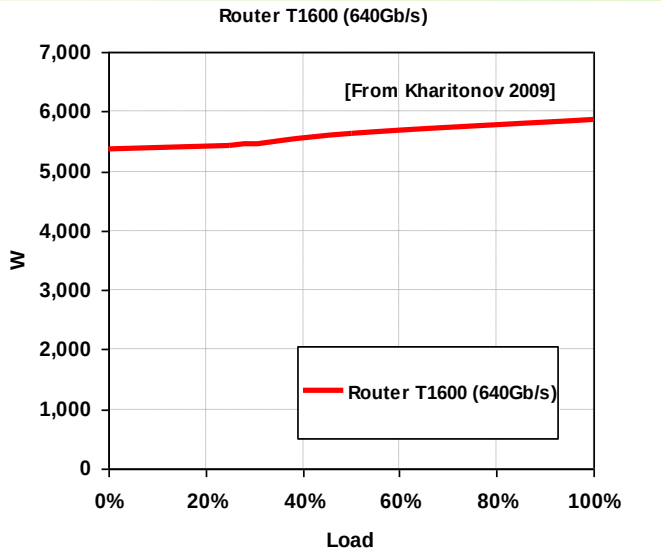
Some Specific Router Limitations

INTERCONNECTS

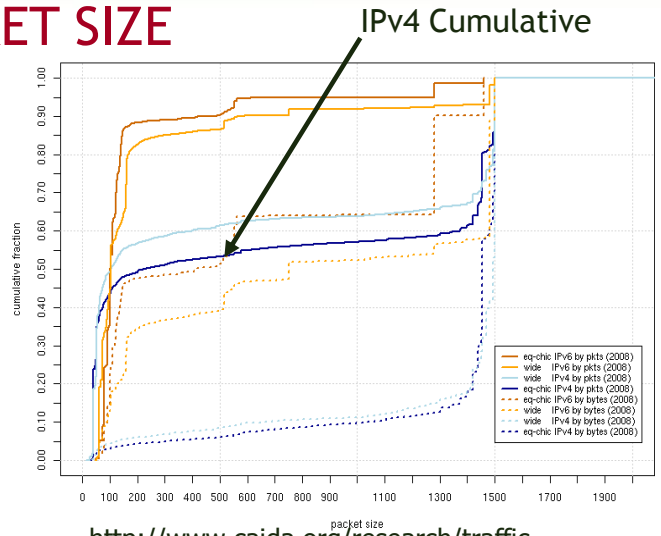


ENERGY DOES NOT FOLLOW LOAD



D.Kharitonov, "Time-Domain Approach to Energy Efficiency: High-Performance Network Element Design" 2009 IEEE GLOBECOM Workshops

PACKET SIZE



http://www.caida.org/research/traffic-analysis/pkt_size_distribution/graphs.xml

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Focus Statement for Core Switching and Routing

Focused on components, technologies, systems, algorithms and protocols at the data link layer (L2), the network layer (L3) and the transport layer (L4) as well as interactions with lower and higher layers and research efficiencies that can be obtained from cross-layer optimizations and joint designs

- **Network equipment hardware (routers and switches)**
  - Architecture and components
  - Functions, features and dimensioning
  - Low energy technologies (including electronics, photonics, etc)
  - Power measurements
- **Network topologies and architectures**
  - Tradeoff between optical and electronic data transport
  - Optimal joint IP-optical network design
  - Packet versus circuit-switched architectures
  - Energy efficient and simplified routing
- **Integration of application and transport layers**
  - Cross-layer optimization for efficient content distribution
- **Traffic engineering**
  - Bandwidth allocation & traffic grooming
  - Elimination of over-provisioning
  - Efficient protection and restoration
  - Multicasting, elimination of junk and redundant traffic ….
- **Network management, operation and control**
  - Quality of service support
  - Network-wide reconfiguration and control of network elements (offline or online). Holistic, end to end approach
  - Protocols and algorithms for managing and controlling network elements
  - Control and data plane
  - Energy and traffic monitoring

Working Group Membership

- Athens Information Technology (AIT)
- Bell Labs *(Chair: Thierry Klein)*
- Broadcom
- Chunghwa Telecom
- Columbia University
- Dublin City University
- Electronics and Telecommunication Research Institute (ETRI)
- Energy Sciences Network / Lawrence Berkeley Labs
- Politecnico di Milano
- Freescale Semiconductor
- Fujitsu
- Huawei Technologies
- IBBT
- IIIT Delhi
- INRIA
- KAIST
- Karlsruhe Institute of Technology
- Nippon Telegraph and Telephone Corporation
- Politecnico di Torino
- Samsung Advanced Institute of Technology (SAIT)
- Seoul National University
- University of Manchester
- University of Melbourne
- University College London
- University of Cambridge
- University of Leeds *(Co-Chair: Jaafar Elmirghani)*
- University of New South Wales
- University of Toronto

28 members organizations with 67 individual members

Energy Efficiency Improvement Opportunity

- Provide assessment of potential opportunities for power efficiency improvements in packet networks
  - Include the electronically switched portion of a service provider network, including IP, Ethernet and OTN
  - Excluding fixed and wireless access networks
  - Excluding optical transport
  - Excluding opportunities for traffic reduction, e.g. via caching
- Goal is to assess the opportunity for energy efficiency improvement with a realistic path towards realization within the GreenTouch timeframe
- Determine “independent” dimensions so that power efficiency numbers can be multiplied to arrive at overall efficiency opportunity

Background and Assumptions

- Timeframe:
  - Consistent with GreenTouch timeframe
  - Algorithms, architectures and technologies that can be demonstrated by 2015
  - With evolutionary improvements through 2020
  - Applied to 2020 traffic
  - Comparison with 2010 traffic and 2010 technologies

- Assumptions:
  - Consider the traditional IP packet data network framework
  - Alternative paths and technologies are possible, but more speculative and are not expected to fit in the timeframe:
    - Optical burst switching
    - Content centric networking
    - Adiabatic switching, quantum dot cellular automata, ….

Overall Efficiency Opportunity

- Defined 5 independent categories:
  - Chip level components and devices: 15x
  - Network element design: 1.5x
  - Network architecture: 2x
  - Dynamic resource management: 3x
  - Power utilization efficiency: 2x

- **Overall power efficiency opportunity: 270x**

- Caveats:
  - Numbers are best current estimates of efficiency improvement opportunity
    - Large degree of uncertainty especially around network element architecture and network architecture
  - Optimistic estimates since not clear if and how all the targets can be achieved
  - Pessimistic estimates since constrained to current IP packet network architectures and further-out technologies not considered

Research Targets by Functional Topic (1)

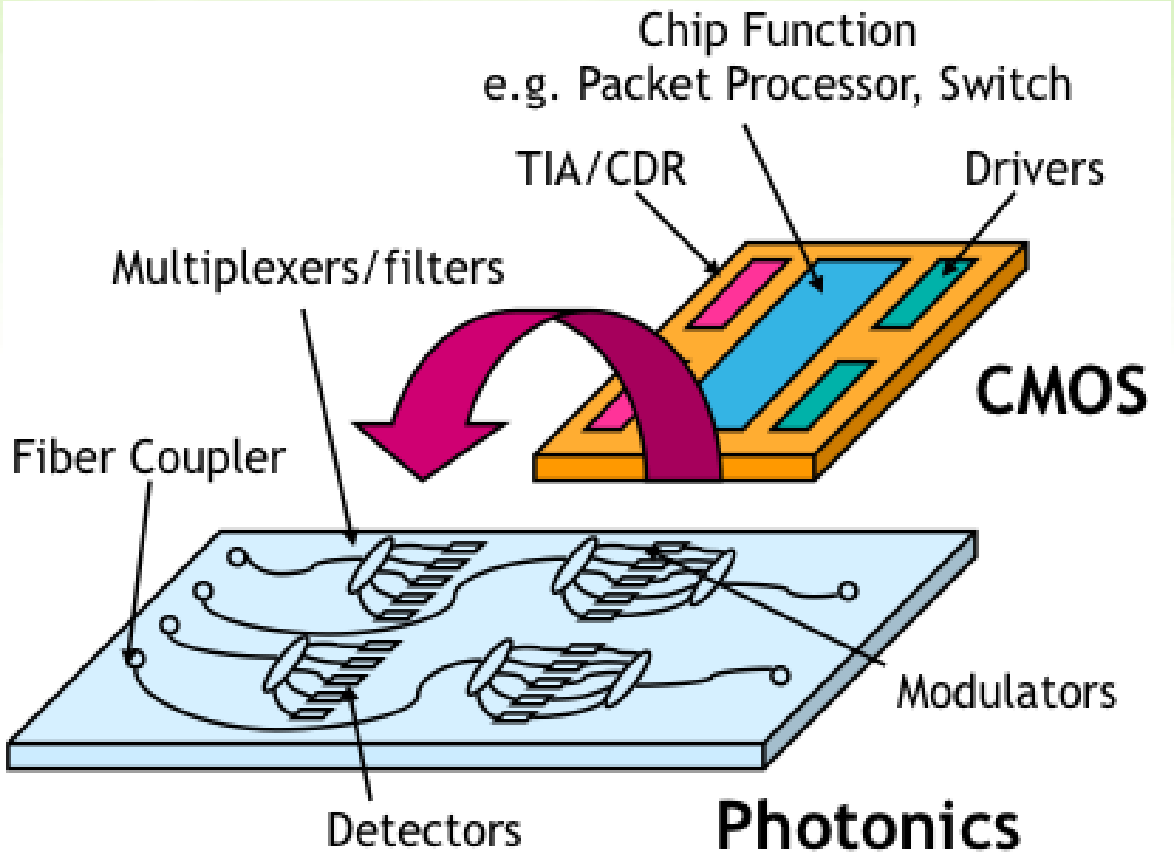
Research Target	Target
Chip Level Components and Devices	
Low power electronics and photonics	3x – 10x
Opto-electronic integrated circuits	3x – 10x
Network Element Design	
Scalable and energy efficient router architectures for peta-bit routers	1.5x
Simplified and energy efficient protocols to eliminate unnecessary and redundant packet processing. Energy efficient software	
Integrated transceiver and wavelength circuit switching fabric operating in a core network to eliminate routing infrastructure and reduce layer-2 switch energy/bit for targeted services	10x
Network Architecture	
Network architectures, topologies and joint IP-optical design	3x – 10x
Energy efficient content routing (content router design, protocols and content placement and replacement algorithms)	10x
Energy optimized combined source and channel coding designed for end to end service dependent efficiency	

Research Targets by Functional Topic (2)

Research Target	Target
Dynamic Resource Management	
Rate adaptation and sleep cycles (processors, buffers, switch fabrics, linecards, router)	2x - 4x
Energy efficient routing	2x
Energy aware scheduling algorithms designed for delay tolerant services that enable end to end buffereless transmission respecting service QoS requirements	
Power aware protection and restoration	2x
Power Utilization Efficiency	
Passive cooling and advanced thermal management	1.5x

- Requires equipment and network models with energy equations to determine overall energy efficiency improvement opportunity
- Gain understanding into which research targets are additive and multiplicative
- Gain understanding into most impactful research areas

SCORPION
Silicon Photonic Interconnects and Single-Chip Linecard



Contributing Members

Bell Labs

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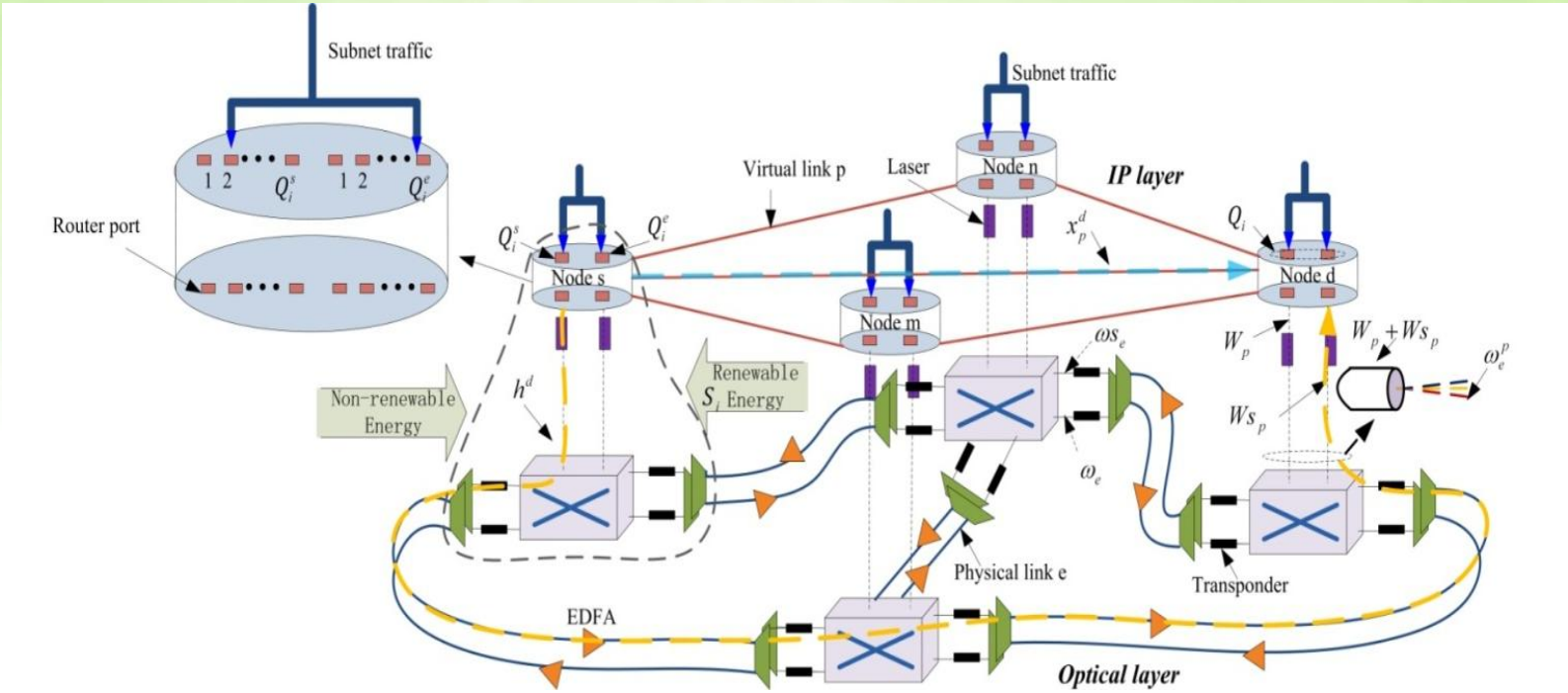
OPERA: OPtimal End to end Resource Allocation



Contributing Members

UNIVERSITY OF LEEDS

UNIVERSITY OF CAMBRIDGE

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • CANBERRA • AUSTRALIA

Fondazione Politecnico di Milano

ATHENS INFORMATION TECHNOLOGY 2002 — AIT CENTER OF EXCELLENCE FOR RESEARCH AND EDUCATION

Perceptum ex Optimus

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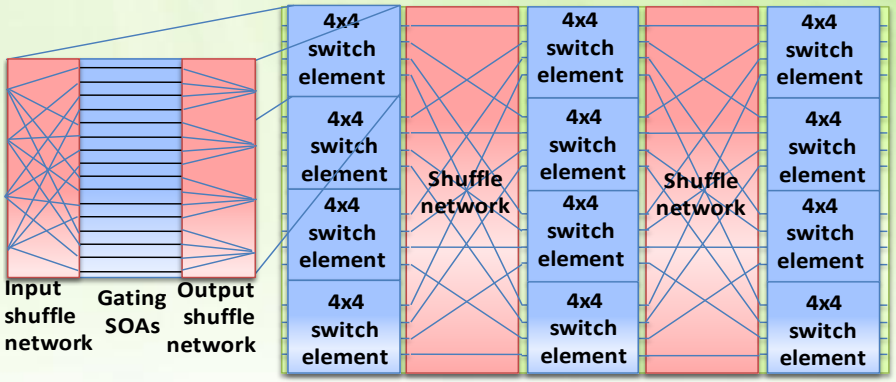
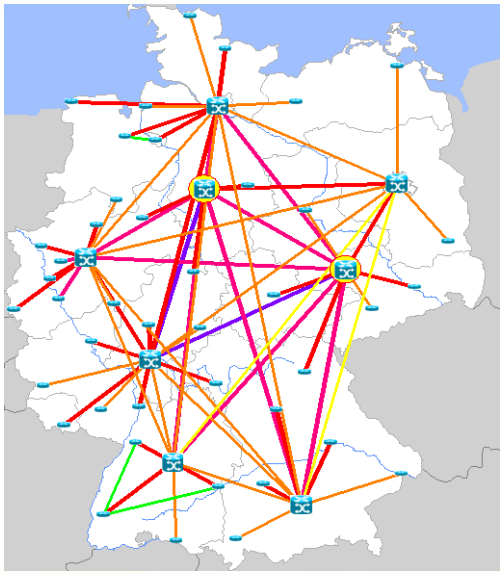
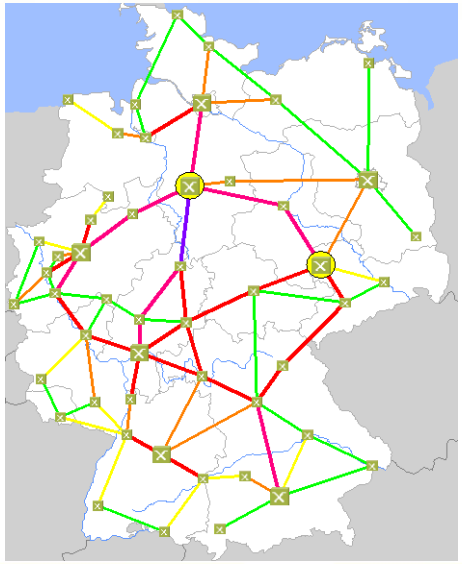
STAR: SwiTching And tRansmission



IP layer



WDM layer



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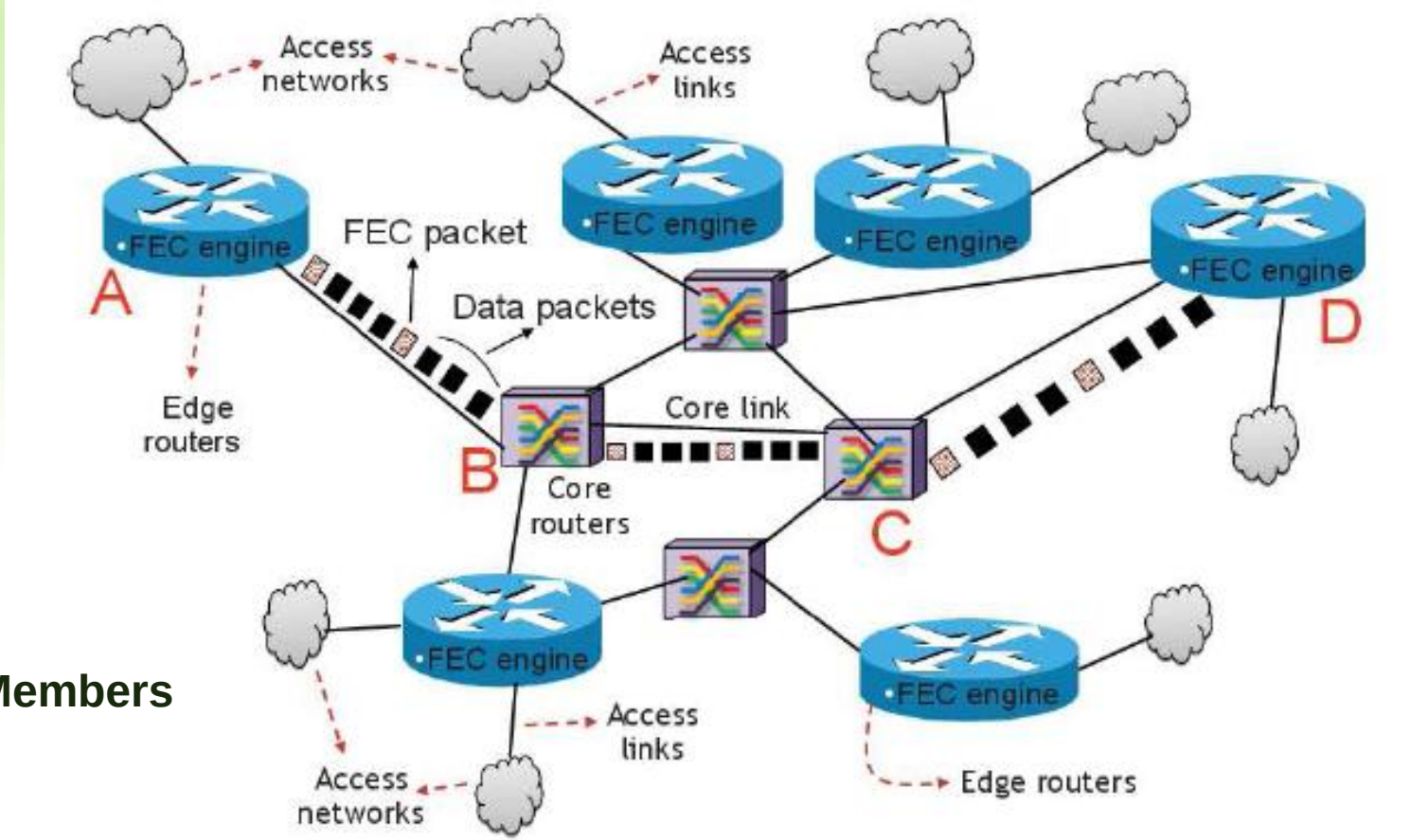
ZeBRA: Zero Buffer Router Architecture



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

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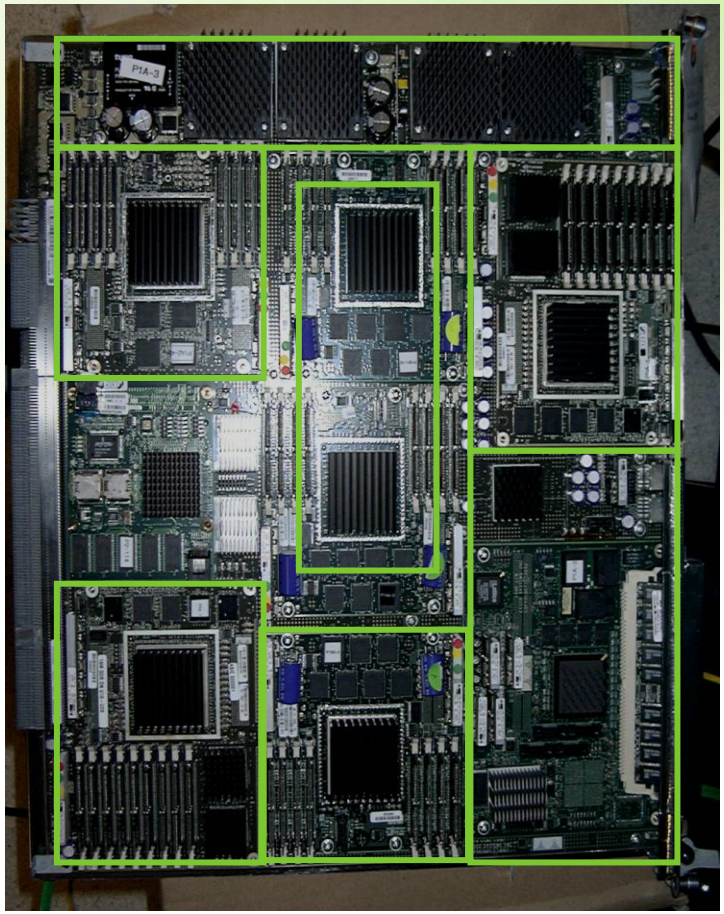
REPTILE: Router Power Measurements



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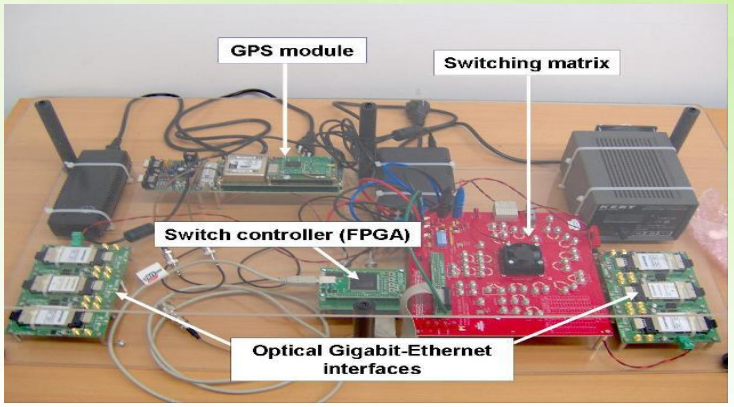
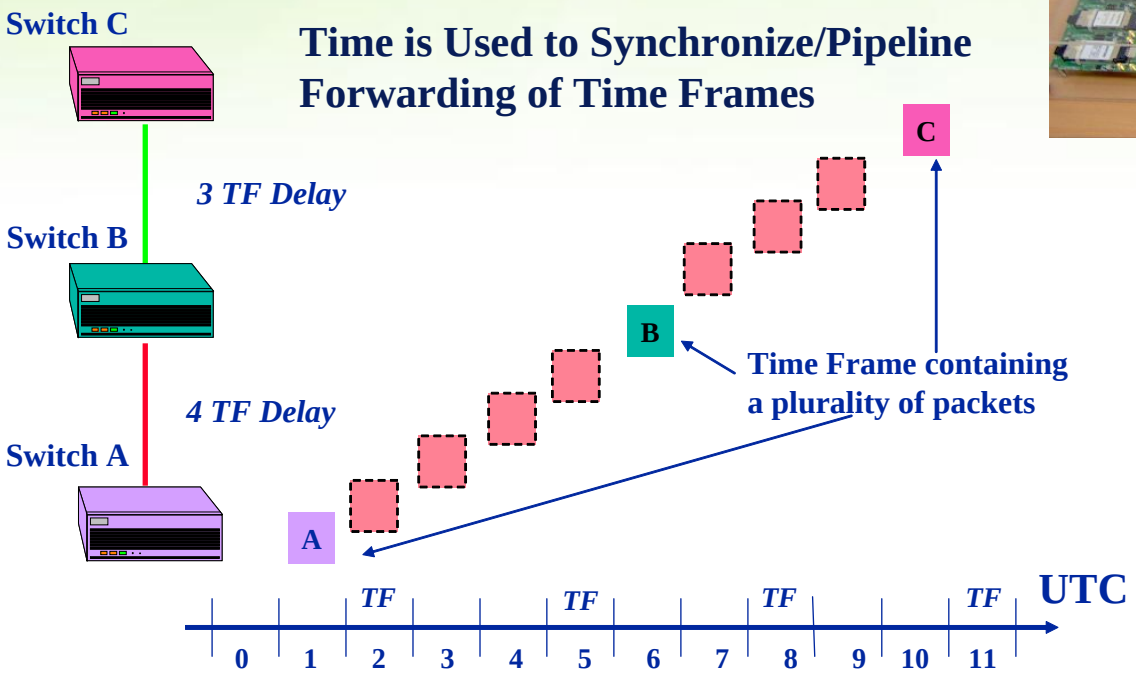
TIGER: TIme for a Greener Internet





Contributing Members

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Politecnico di Torino 1859 1906

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SEASON
Service Energy Aware Sustainable Optical Networks

Contributing Members

Bell Labs

University of Toronto

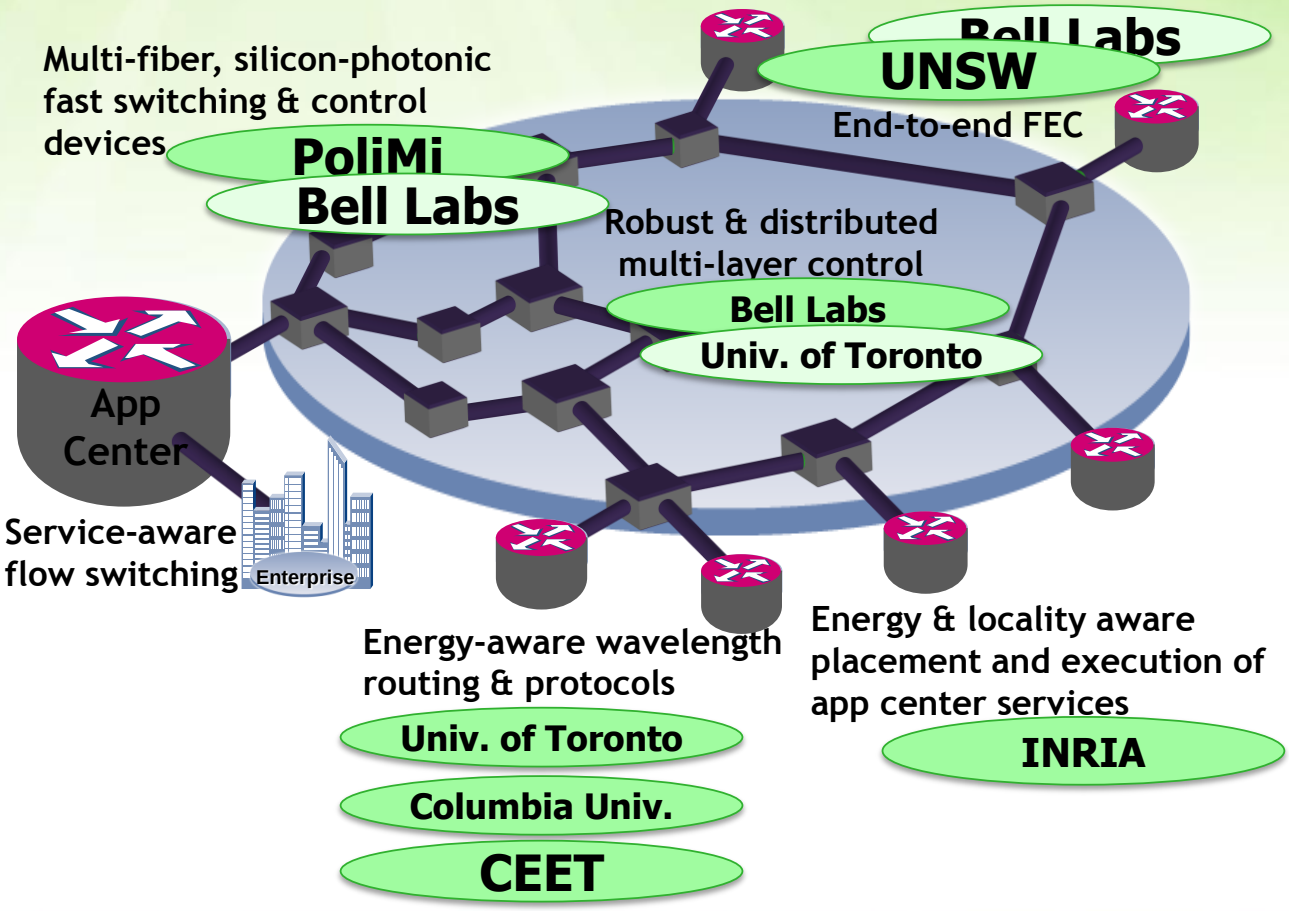
UNSW The University of New South Wales Sydney • Canberra • Australia

ceet centre for energy-efficient telecommunications Bell Labs and University of Melbourne

Fondazione Politecnico di Milano

French National Institute for Research in Computer Science and Control | INRIA

Columbia University in the City of New York



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Research Targets and Mapping to Projects (1)

Research Target	Projects
Chip Level Components and Devices	
Low power electronics and photonics	SCORPION, STAR
Opto-electronic integrated circuits	
Network Element Design	
Scalable and energy efficient router architectures for peta-bit routers	SCORPION
Simplified and energy efficient protocols to eliminate unnecessary and redundant packet processing. Energy efficient software	
Integrated transceiver and wavelength circuit switching fabric operating in a core network to eliminate routing infrastructure and reduce layer-2 switch energy/bit for targeted services	SEASON
Network Architecture	
Network architectures, topologies and joint IP-optical design	OPERA, TIGER, ZeBRA, STAR, SEASON
Energy efficient content routing (content router design, protocols and content placement and replacement algorithms)	CROCODILE (to be approved)
Energy optimized combined source and channel coding designed for end to end service dependent efficiency	SEASON

Research Targets and Mapping to Projects (2)

Research Target	Projects
Dynamic Resource Management	
Rate adaptation and sleep cycles (processors, buffers, switch fabrics, linecards, router)	OPERA, ZeBRA, REPTILE
Energy efficient routing	STAR, OPERA
Energy aware scheduling algorithms designed for delay tolerant services that enable end to end buffereless transmission respecting service QoS requirements	SEASON
Power aware protection and restoration	OPERA
Power Utilization Efficiency	
Passive cooling and advanced thermal management	