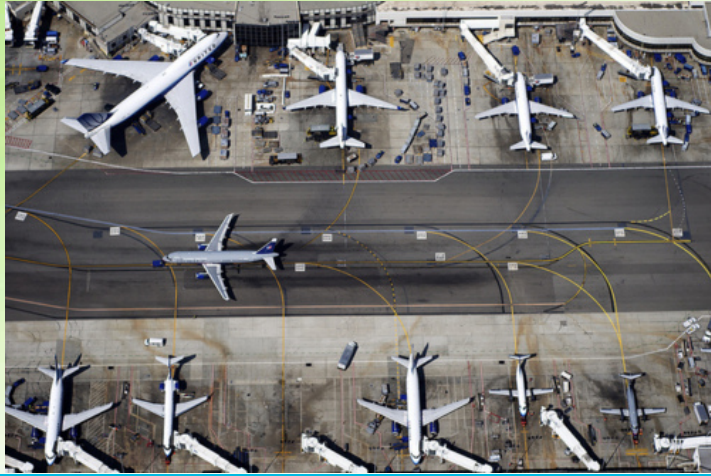# GreenTouch Vision, Targets and Research Activities

Prof. Jaafar Elmirghani, University of Leeds
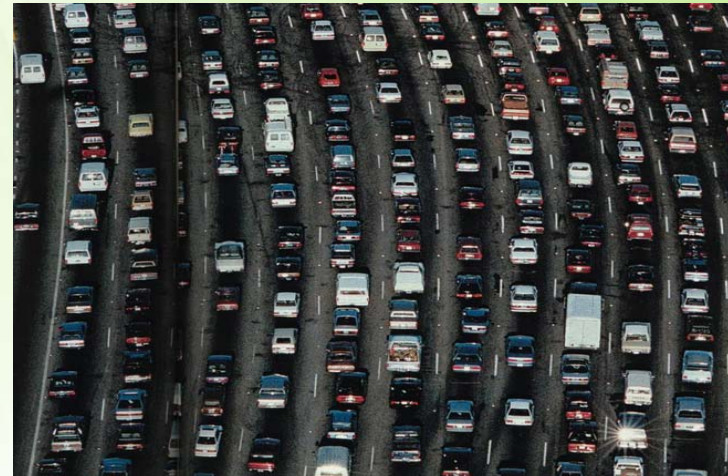
j.m.h.elmirghani@leeds.ac.uk

Co-Chair, GreenTouch Wired Core & Access Networks Committee

ICT ENVIRONMENTAL IMPACT TODAY

Global aviation industry

50 million cars

Global ICT Emissions: 2.3%, Growing at 4% YoY

GeSI "SMARTer 2020: The Role of ICT in Driving a Sustainable Future", 2012

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GREEN MAKES ECONOMIC SENSE

NETWORK ENERGY USE

+27%

INCREASE

2012 to 2106

INTERNET

=5th

HIGHEST COUNTRY

If the internet was a country: energy consumption is higher than Russia and a little less than Japan

NETWORK

~75%

ENERGY BILL

70 to 80% overall energy bill of an operator
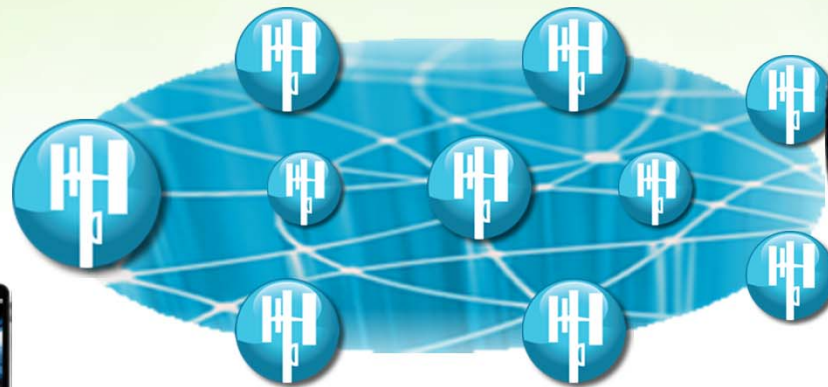➢ RAN: +70% of network electricity cost
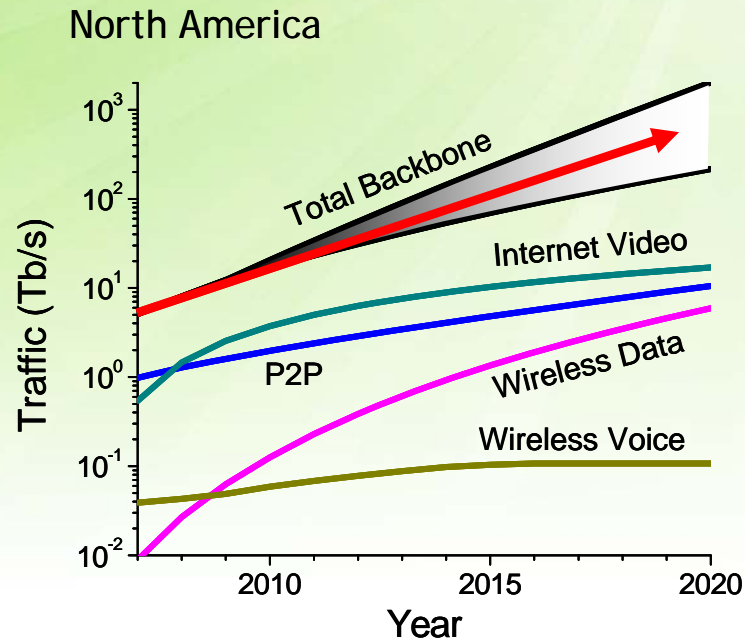
ENERGY BILL

7-20%

OPERATORS OPEX

From 7% in mature countries to +20% in emerging countries

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# THE NEW WIRELESS WORLD OF TODAY

Global Users

Anywhere, Any time, Any Device

Wireless, Video

HD, 3D, …

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MASSIVE DATA TRAFFIC GROWTH

North America

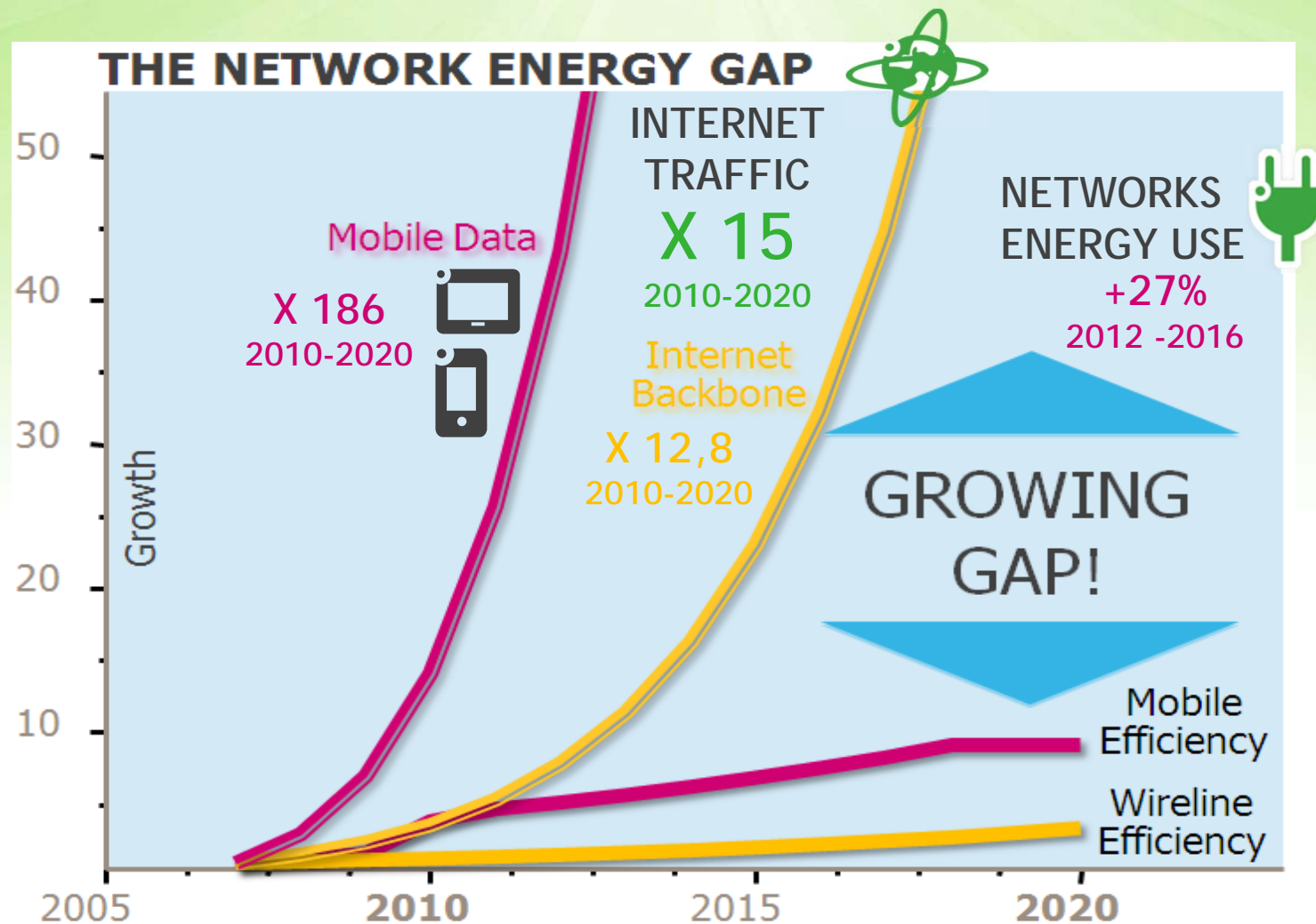Traffic (Tb/s) vs Year graph showing: Total Backbone, Internet Video, P2P, Wireless Data, Wireless Voice

Data from: RHK, McKinsey-JPMorgan, AT&T, MINTS, Arbor, ALU, and
Bell Labs Analysis: Linear regression on log(traffic growth rate) versus log(time) with Bayesian learning to compute uncertainty

5,000,000 towers

78 Mtons of CO_2

5 000 000 000 people without broadband

- Slow-down in technology improvements
- Network energy efficiency only increasing at 10-15% per year
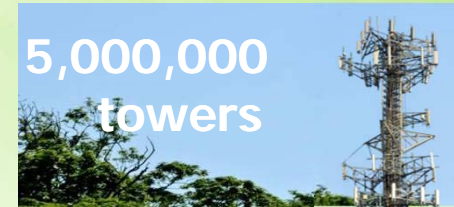
Fundamental question:

Support the traffic growth in a sustainable and economically viable way throughout the world

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DOING NOTHING IS NOT AN OPTION

THE NETWORK ENERGY GAP

Mobile Data
X 186
2010-2020

INTERNET TRAFFIC
X 15
2010-2020

Internet Backbone
X 12,8
2010-2020

NETWORKS ENERGY USE
+27%
2012 -2016

GROWING GAP!

Mobile Efficiency

Wireline Efficiency

Growth

2005   2010   2015   2020

Energy Efficiency is a Necessity for the ICT Industry

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GREENTOUCH (www.greentouch.org)

- **Bell Labs Initiated Global Research Consortium** representing industry, government and academic organizations

- **New Innovation Model for sustainability**

- Launched in May 2010

- Focus on **energy efficiency, sustainability** and growth

- **Holistic** and **ambitious**: Goal of 1000x

- **60 member organizations with 350+ leading scientists**

- Recognized by the **World Economic Forum** as an industry-led best practice toward sustainability

- Moving from fundamental research into the **pre-competitive area** through standardization

- Leading **Green ICT**: cooperation with other NGOs such as GeSI, ITU-T, GreenGrid, Carbon Trust, ITRS

> **Deliver by 2015 Architectures, Specifications and Roadmap and Demonstrate Key Technologies to Increase Network Energy Efficiency by a Factor 1000 Compared to 2010**

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WHY NETWORK ENERGY EFFICIENCY?

INCREASE

Green Services

GROWTH

Revenue from Services

$$Network\ Efficiency = \frac{Total\ Traffic\ Delivered\ to\ User}{Total\ Power\ per\ User}$$

Bits per second

Watts

REDUCE

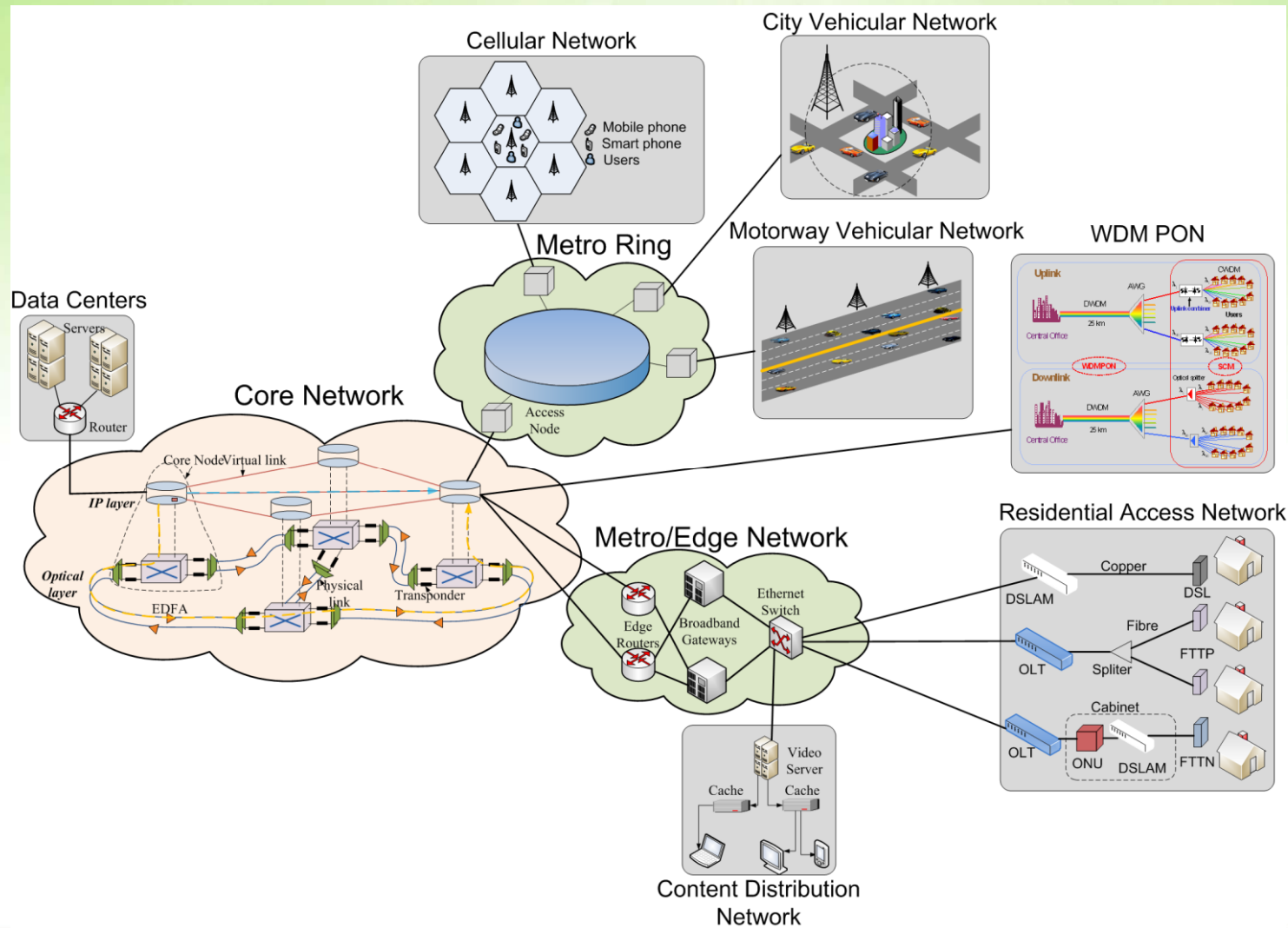Carbon Footprint

Costs

Makes both Environmental and Economic Sense

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End-to-end Network

SOME RESEARCH PROJECTS

25+ PROJECTS

- Beyond Cellular – Green Mobile Networks
- Virtual Home Gateway
- Optimal End-to-End Resource Allocation
- Service Energy Aware Optical Networks
- Green Transmission Technologies
- Minimum Energy Access Architectures
- Single-Chip Linecards
- Large-Scale Antenna Systems
- Highly-Adaptive Layer Mesh Networks
- Massive MIMO

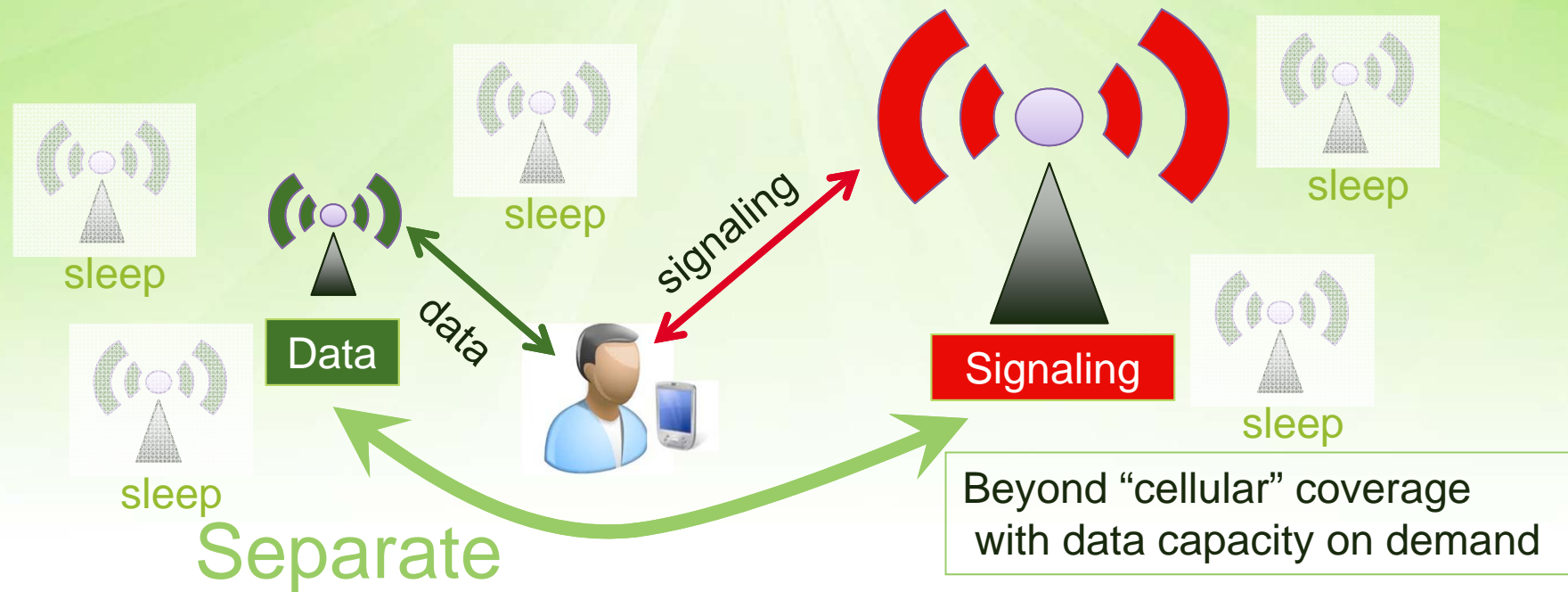Fondazione Politecnico di Milano

swisscom

UNIVERSITY OF LEEDS

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

HUAWEI

ceet centre for energy-efficient telecommunications

Bell Labs

imec

Bell Labs

SAMSUNG
SAMSUNG ADVANCED
INSTITUTE OF TECHNOLOGY

GreenTouch

BEYOND CELLULAR GREEN GENERATION

sleep

sleep

Data

data

signaling

sleep

sleep

Signaling

sleep

Separate

Beyond "cellular" coverage with data capacity on demand

Opportunities for sustainability:

• System designed for energy efficiency

  • Separate capacity from coverage

  • Optimise signalling transmission

  • Lean access to system

• Cope with massive amount of low data rate services

Challenges:

• New system architecture

• Re-invent mobility management

• Agile management, context aware, network with memory

• Hardware for fast reconfiguration

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BIT-INTERLEAVING PON DELIVERS >10x BETTER EFFICIENCY

10 Gb/s   ~10 Mb/s
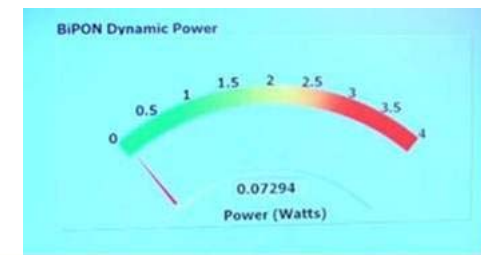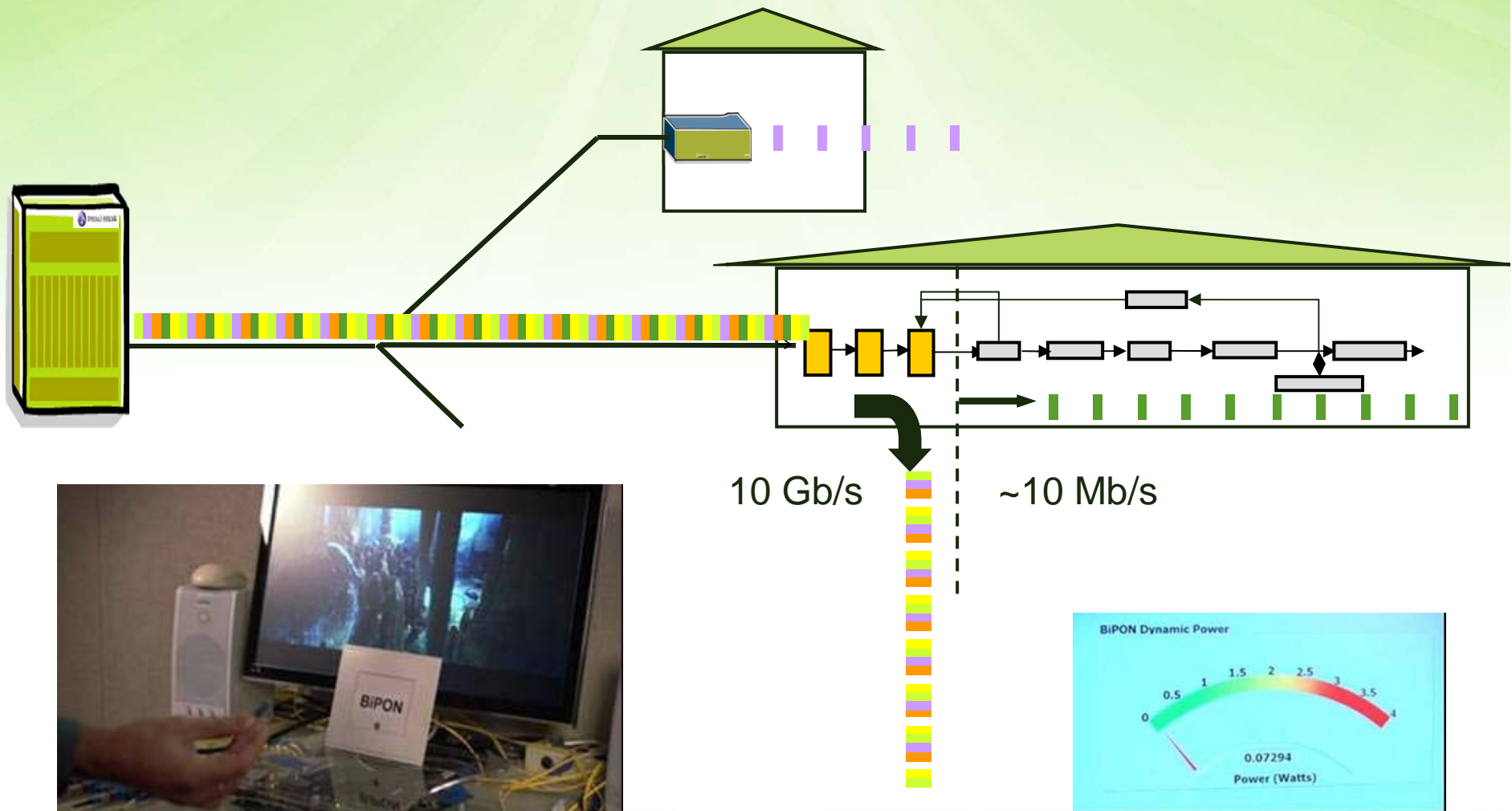
Silicon Photonic Interconnects and Single-Chip Linecard
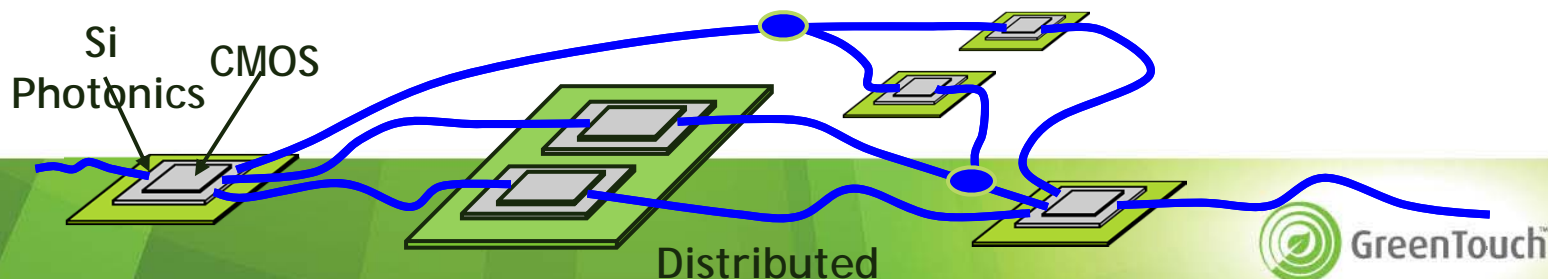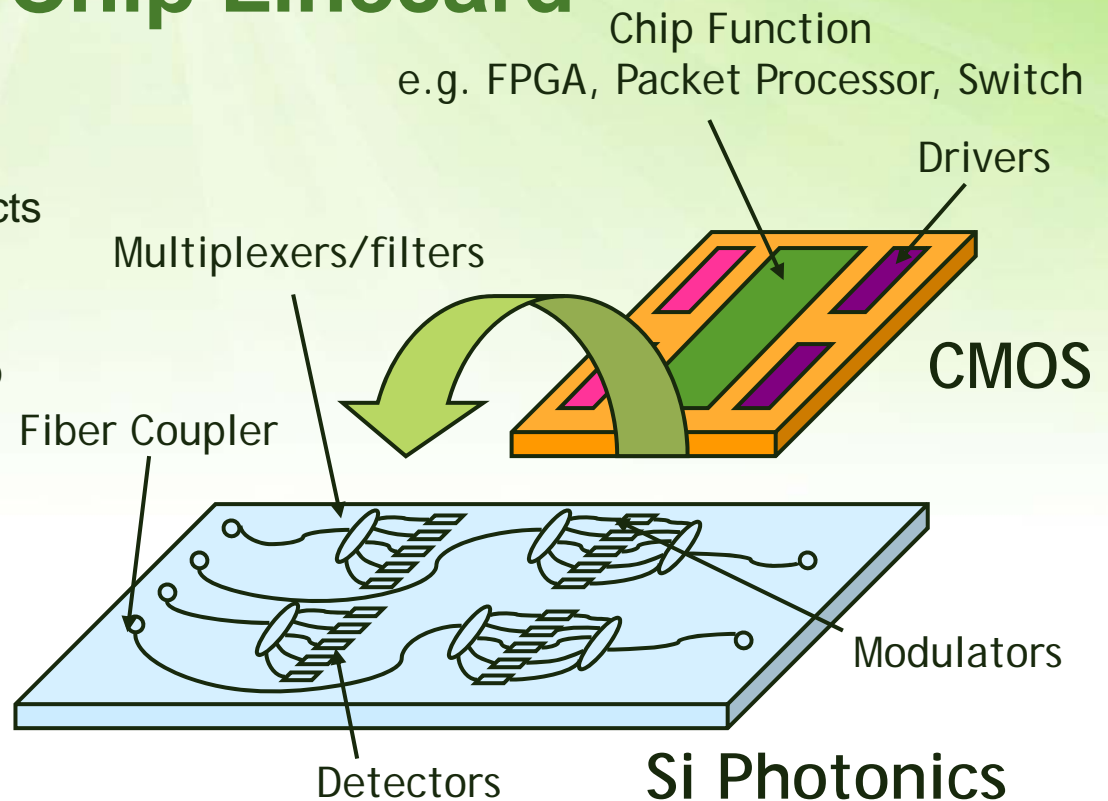
- **Main ideas:**
  - Hybrid integration of silicon photonics with CMOS
  - Reduce the number of interconnects on a linecard
  - Integrate all packet processing functionalities onto a single chip to minimise interconnects

- **Partners:**
  - Bell Labs

- **Deliverables:**
  - Silicon-photonics interface device demo
  - Photonic CMOS integration demo
  - Single chip router CMOS/photonics ASIC

Chip Function
e.g. FPGA, Packet Processor, Switch

Drivers

Multiplexers/filters

CMOS

Fiber Coupler

Modulators

Detectors

Si Photonics

Si Photonics   CMOS

Distributed

GreenTouch

OPERA: OPtimal End to end Resource Allocation

▪**Main ideas:**
- Optimum architectures, routing protocols and resource allocation strategies at different time scales
- Protection and restoration resource allocation and energy savings
- Dynamic allocation and management of buffers and packet processing resources
  - Sleep modes for packet processors and buffers
  - Dynamic sizing of buffers
 - Potential implications for new router architectures

▪**Partners:**
- Athens Information Technology
- Politecnico di Milano
- University of Cambridge
- University of Leeds **(Lead)**
- University of New South Wales

▪**Deliverables:**
- Algorithms, design and evaluation
- Integrated evaluation tool
- Lab demo

- **Initial results presented in the WG:**
Optimization framework, min buffers, control protocols, protection, processor adaptation

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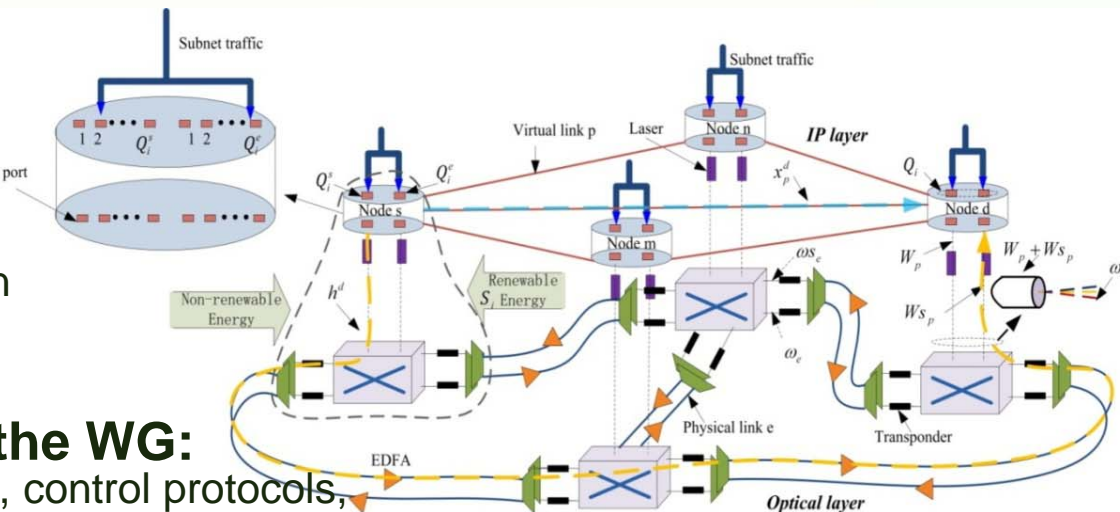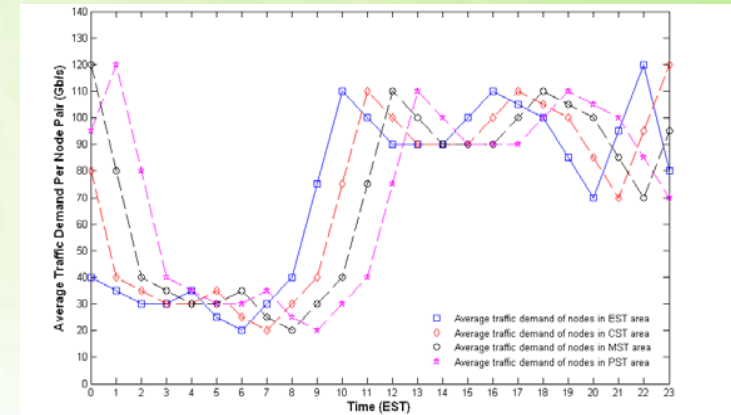
STAR: SwiTching And tRansmission

▪ **Main ideas:**

• Photonic Switch design and optimisation
  – Improving the design of the switch for lower power performance.
  – Use of active-passive integration to replace of the current always on active shuffle networks with their passive equivalents.
  – Integration of on-chip detectors to allow monitoring

• Optimum physical topology design
  – Save energy by reducing IP routing and introducing more point-to-point transmission
  – Investigate power consumption savings obtained through more switching (instead of IP routing) using large switch architectures
  – Design and demonstrate energy efficient large photonic switch architectures
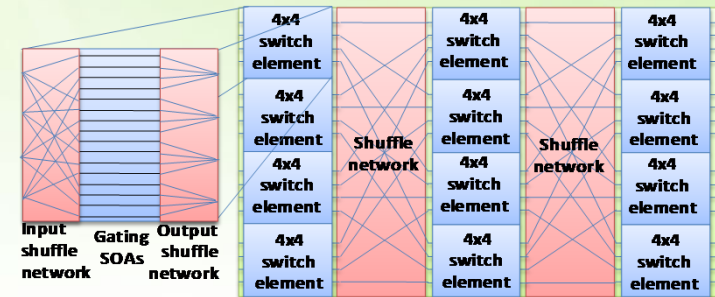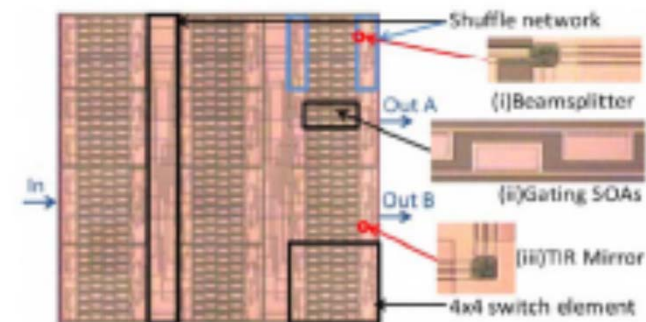
▪ **Partners:**

• University of Cambridge **(Lead)**

• University of Leeds

• Alcatel-Lucent / Bell Labs

▪ **Deliverables:**

• Network simulation, evaluation and optimisation tools

• Low power, large photonic switch architecture

• Lab demonstration

REPTILE: Router Power Measurements

- **Main ideas:**
  - Refine techniques for evaluating router power consumption and relationship between the overall power consumed by a network element and its traffic load
    - As a function of traffic throughput
    - Provide data for network energy consumption models
  - Develop techniques and equipment to enable measurement of network element power consumption at the sub-system and component levels
  - Objective is understand main sources for power consumption and opportunities for rate adaptation / sleep modes

- **Partners:**
  - University of Melbourne **(Lead)**

- **Deliverables:**
  - Testing of the technique on laboratory and deployed network equipment
  - Development and testing of detailed mathematical models
    for power consumption of network equipment under a diverse range of network configurations and loads
  - Application of the model to the GreenTouch reference architecture

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TIGER: TIme for a Greener Internet

■**Main ideas:**

- Combine the potentials of all-optical switching and electronic processing into a system based on Time Driven Switching (TDS)

- By applying the principle of Pipeline-Forwarding (PF), the state of the switches is scheduled in advance, prior to data sending

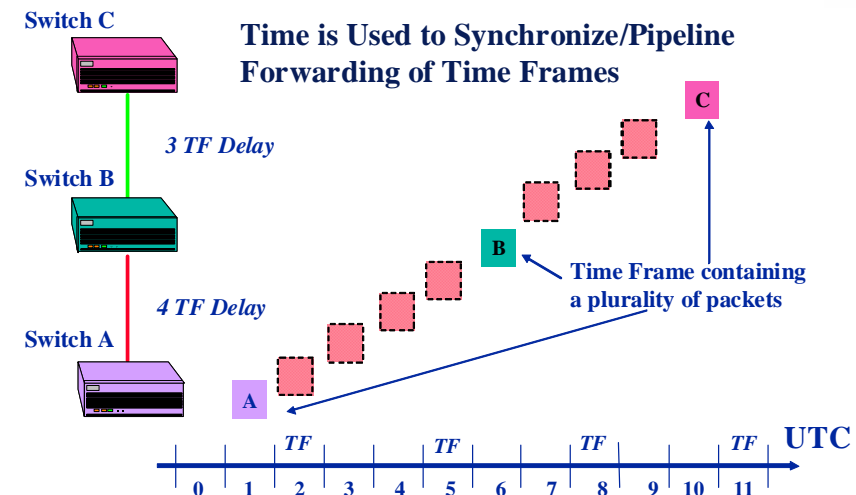- Schedules are coordinated using global time reference
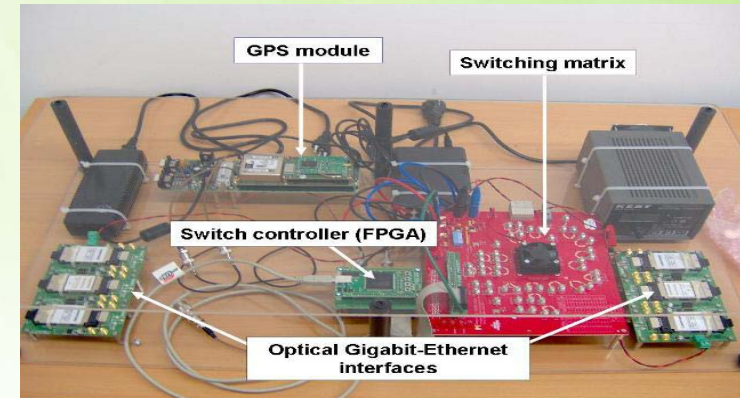
■**Partners:**

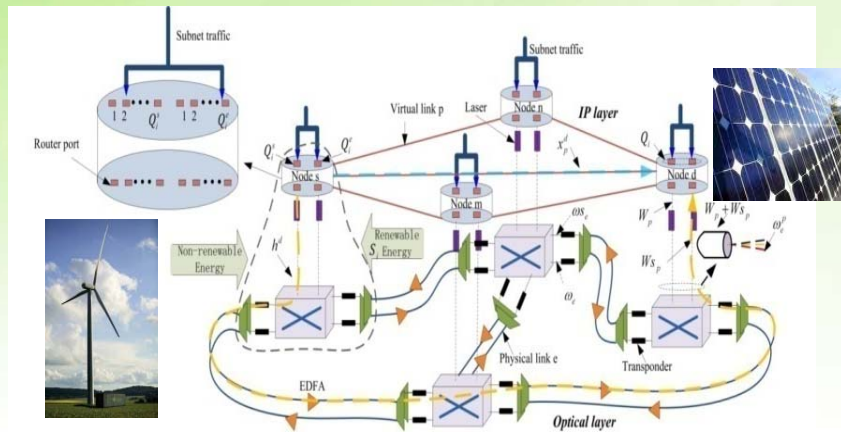- Politecnico di Milano **(Lead)**
- Politecnico di Torino
- Links to SEASON and STAR projects

■**Deliverables:**

- Analysis of transport plane in TDS networks

- Study of control/management plane in TDS networks
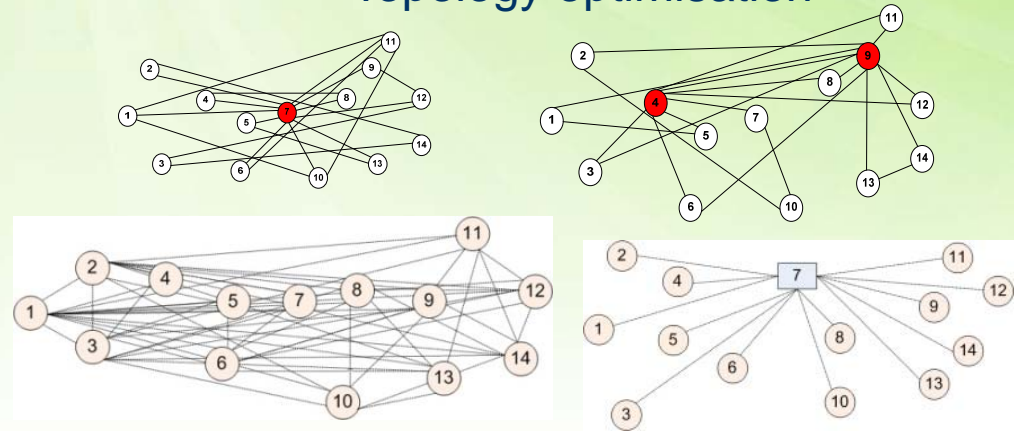
- Interconnection testing and field trials

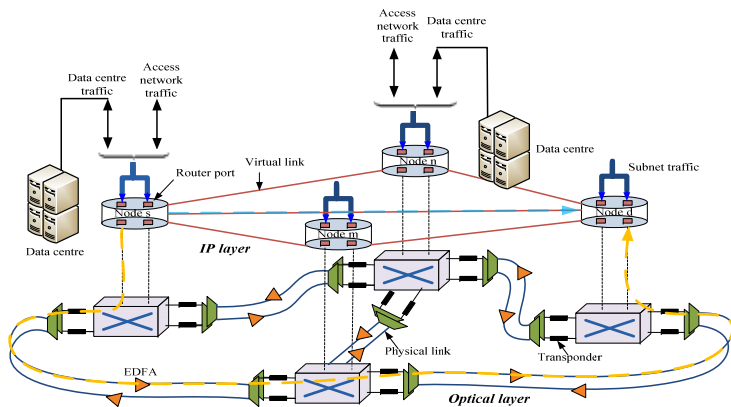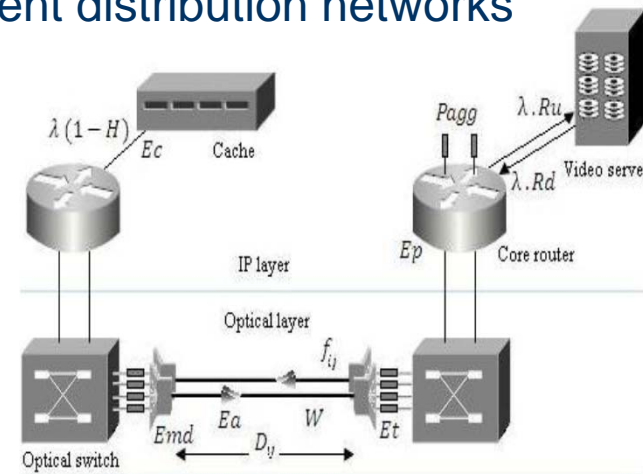# Energy Efficient Network Architectures
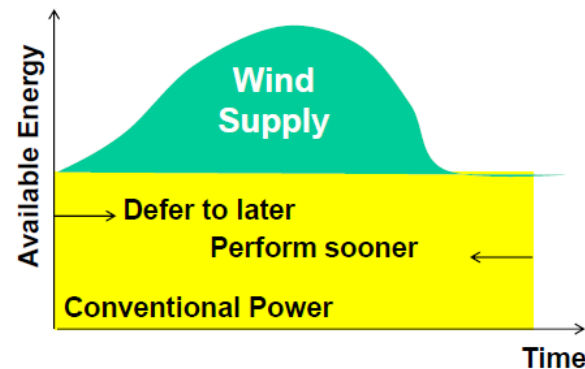
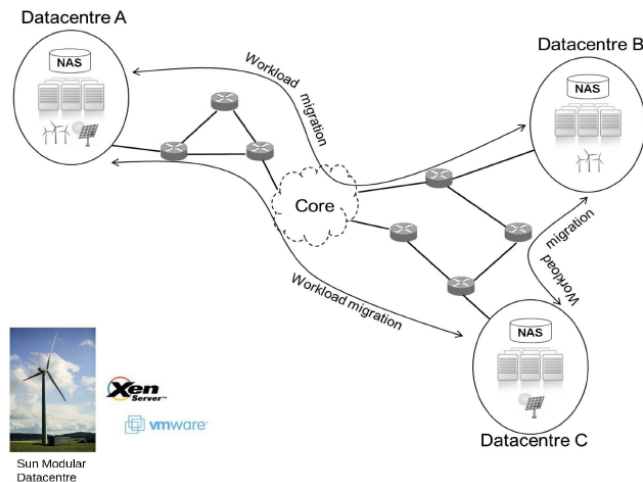## Renewable energy
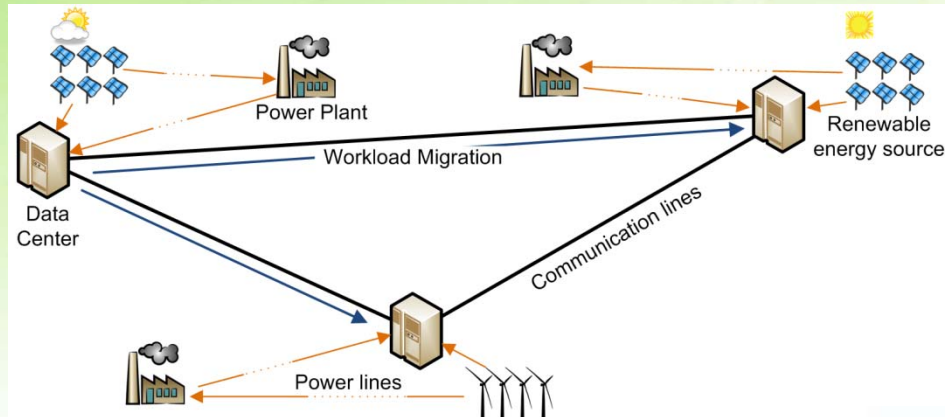

Topology optimisation

Data centres
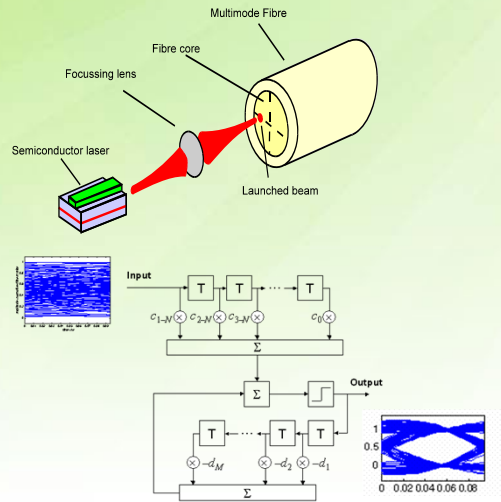

Content distribution networks

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Virtual machine migration between geographically distant data centres

Energy Efficient Components

Data communications

16x16 low power photonic switch
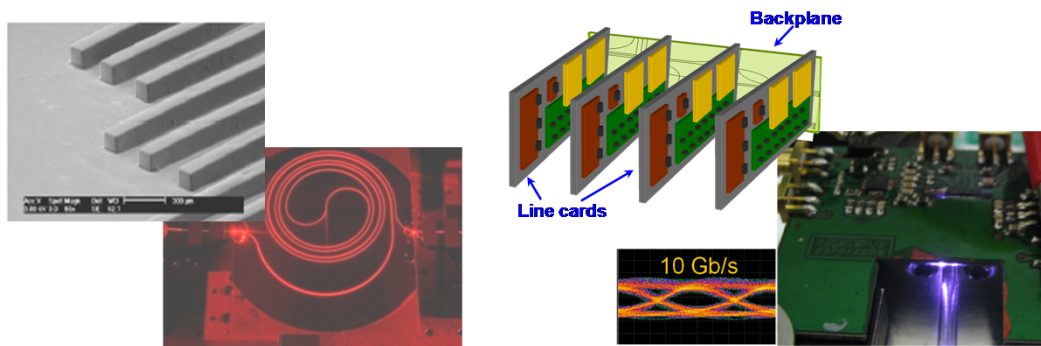

Shuffle network
(i) Beamsplitter
(ii) Gating SOAs
(iii) TIR Mirror
4x4 switch element
In
Out A
Out B
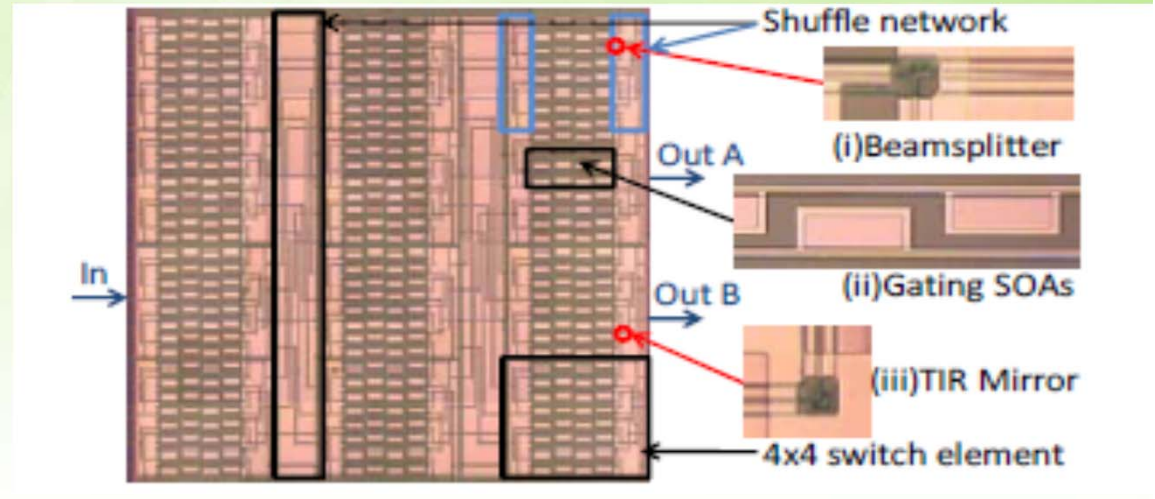
Polymer optical interconnects, backplane

Backplane
Line cards
10 Gb/s

In building distributed antenna systems
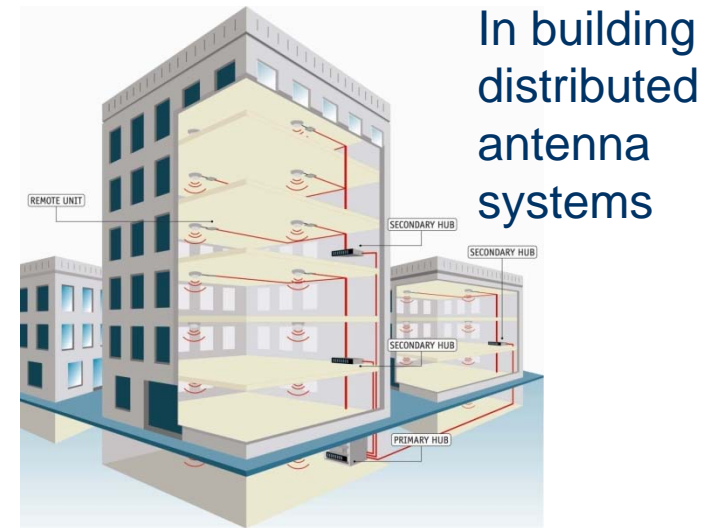
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GREENTOUCH STATUS: WHERE ARE WE?

15+ RESEARCH PROGRAMS & 25 RESEARCH PROJECTS

- Wireless and mobile communications
- Wireline access
- Core networks and optical transmission
- Services, applications and trends

NEW APPROACHES BEING TAKEN

- Devices and low power electronics / photonics
- Architectures, algorithms and protocols
- "Power-follows-load" intelligent management
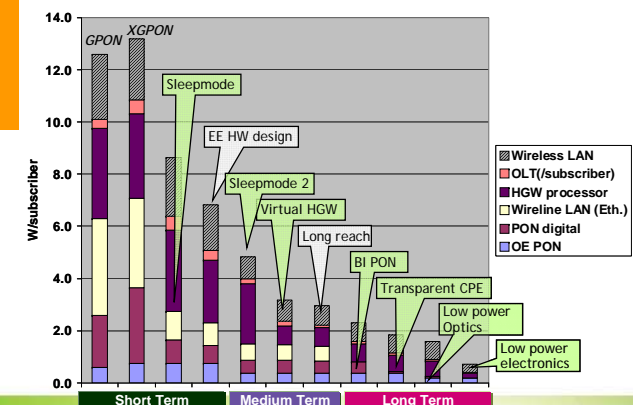- Service and energy optimized networks
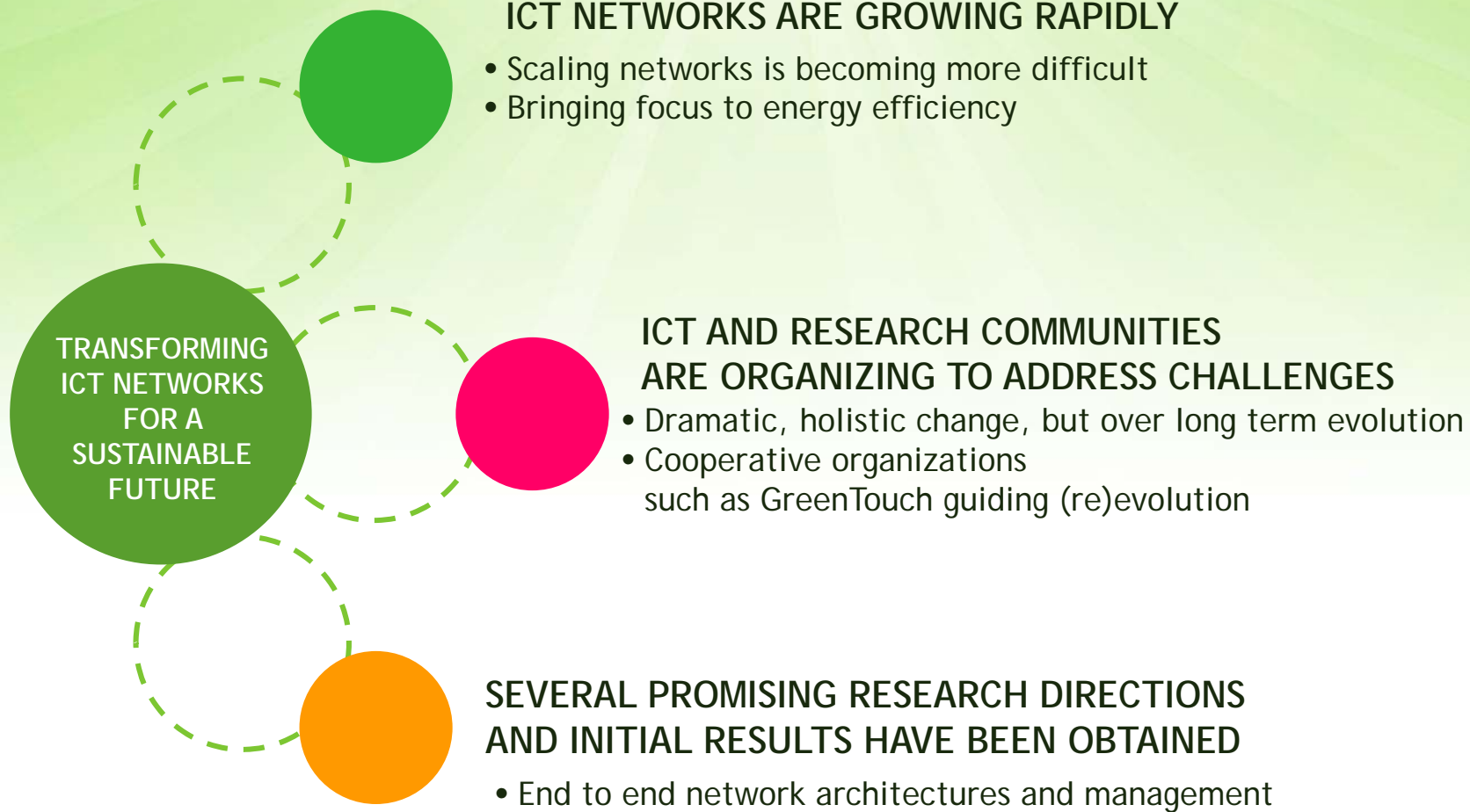
TWO MAJOR PUBLIC DEMONSTRATIONS

- Wireless
- Fiber-to-the-home

COMMON REFERENCE ARCHITECTURE & ROADMAP

- Establish and define common reference architecture and roadmap with strategic research directions

CONCLUSIONS

TRANSFORMING ICT NETWORKS FOR A SUSTAINABLE FUTURE

ICT NETWORKS ARE GROWING RAPIDLY
- Scaling networks is becoming more difficult
- Bringing focus to energy efficiency

**ICT AND RESEARCH COMMUNITIES
ARE ORGANIZING TO ADDRESS CHALLENGES**
- Dramatic, holistic change, but over long term evolution
- Cooperative organizations
  such as GreenTouch guiding (re)evolution

**SEVERAL PROMISING RESEARCH DIRECTIONS
AND INITIAL RESULTS HAVE BEEN OBTAINED**
- End to end network architectures and management

MORE WORK REMAINS!

follow us on **twitter** @Green_Touch

www.alcatel-lucent.com

www.greentouch.org

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Thank You

www.greentouch.org