TRANSFORMING ICT NETWORKS FOR A SUSTAINABLE FUTURE

Dr. Thierry E. Klein
Head of Green Research at Bell Labs / Alcatel-Lucent
Chair of Technical Committee GreenTouch

Alcatel·Lucent

GOING GREEN: NEXT REVOLUTION OF 21ST CENTURY

"How do we get Green out of the talking shop into reality? Remember the Internet in the 80's? Green can be the same motor for innovation and inspire a new wave of economic growth."

Ben Verwaayen
CEO Alcatel-Lucent

"I have always believed that IT is an engine of an efficient economy, it can also drive a greener one."

Michael Dell
Founder and CEO Dell, Inc

Forbes Magazine, Nov. 2009

GREEN
=
MOTOR FOR INNOVATION
+
ECONOMIC DRIVER

Green is the single most important opportunity for the 21st century for all industries and specifically for ICT

Need new business models and innovation and co-creation frameworks

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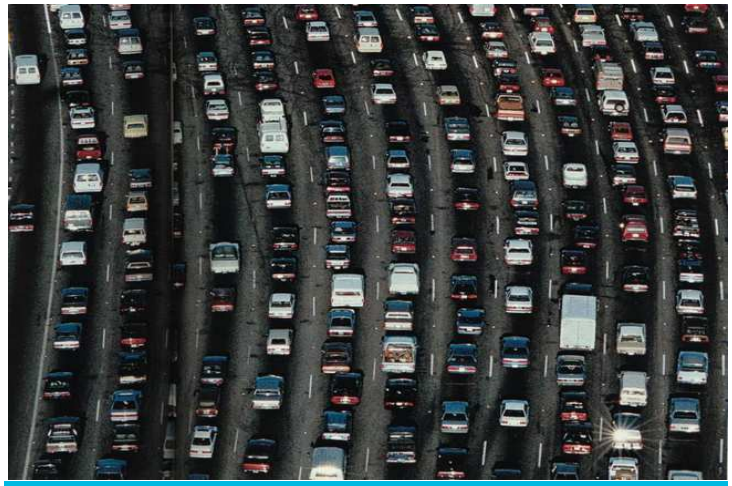
ICT IMPACT TODAY EQUIVALENT TO

Global aviation industry



50 million cars

- Worldwide ICT carbon footprint: 2% = 830 m tons CO2 in 2007
- Expected to grow to 4% by 2020

GREEN MAKES ECONOMIC SENSE

SMARTPHONES

x32

INCREASE

In urban areas
Today: 400 per km^2
2015: 12,800 per km^2

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

A NEW WIRELESS WORLD / INTERNET

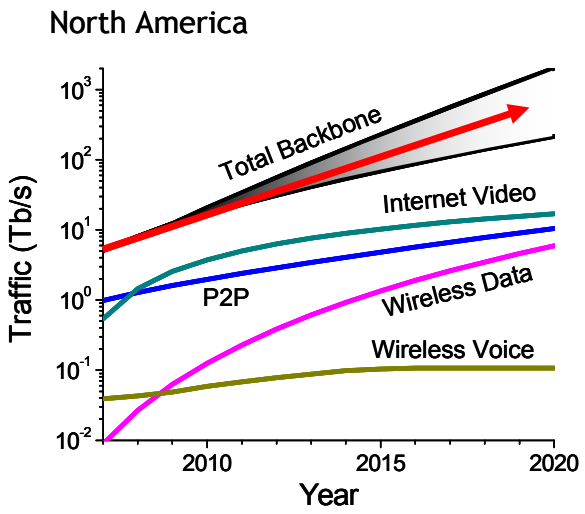
Global Users

Anywhere, Any time, Any Device

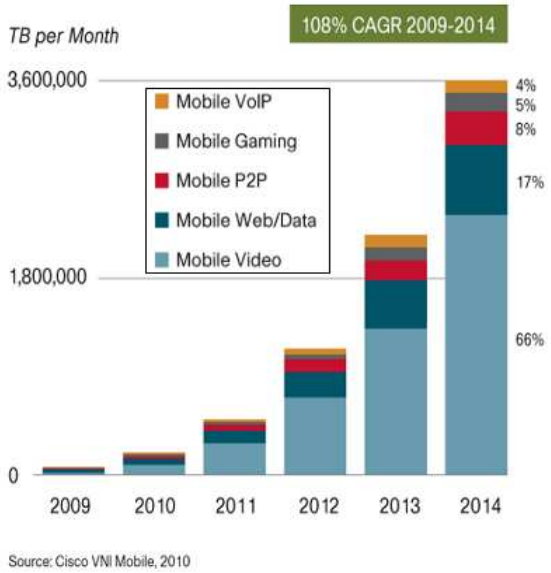
Wireless, Video

HD, 3D, …

MASSIVE DATA TRAFFIC GROWTH



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



Source: Cisco VNI Mobile, 2010

- 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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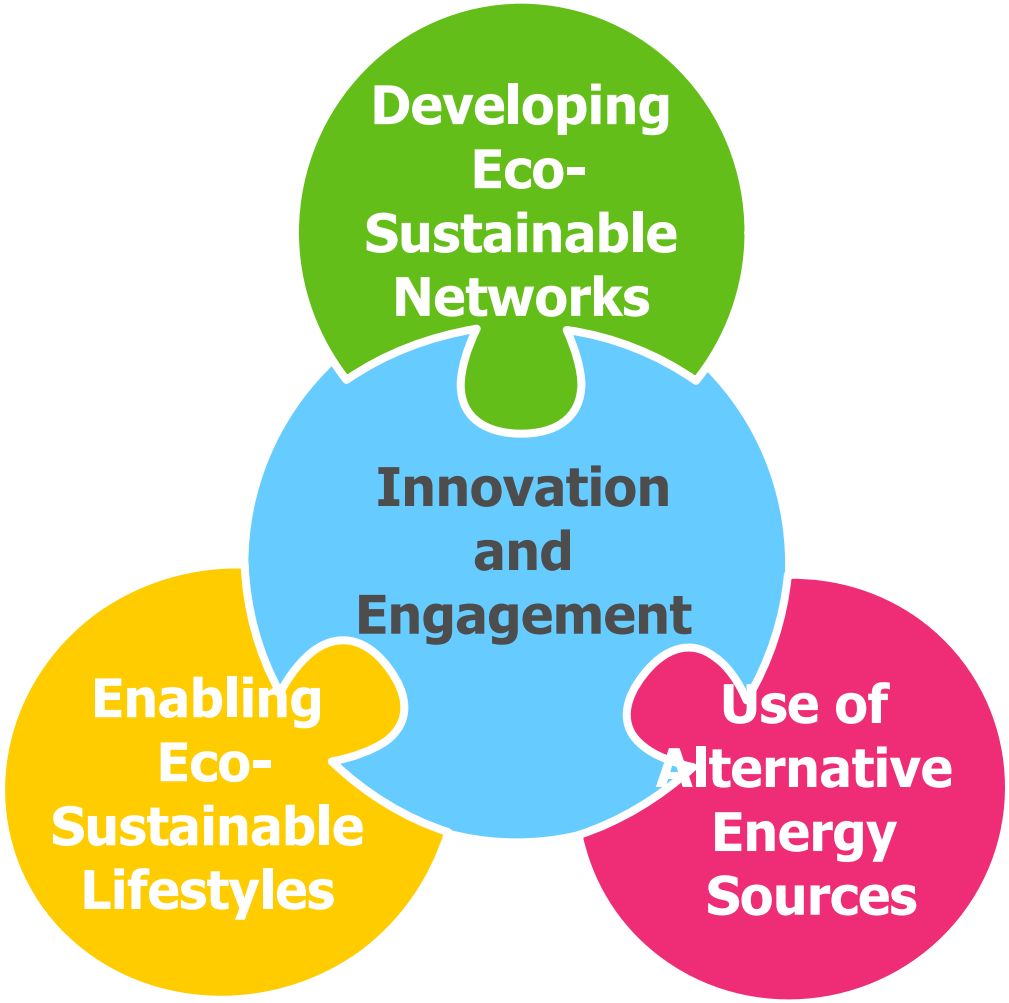
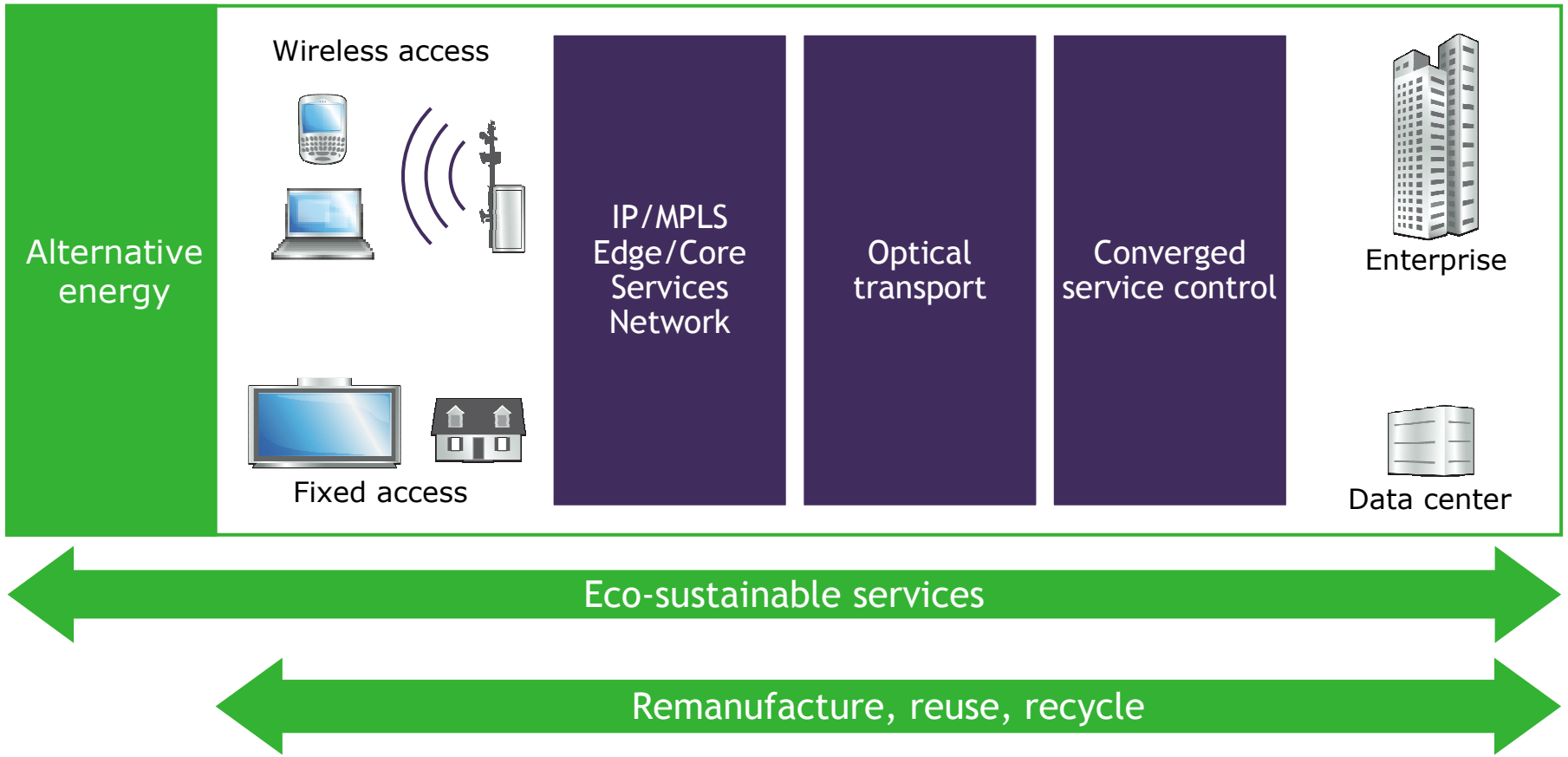
TRANSFORMING COMMUNICATIONS FOR A SUSTAINABLE WORLD



DEVELOPING ECO-SUSTAINABLE NETWORKS

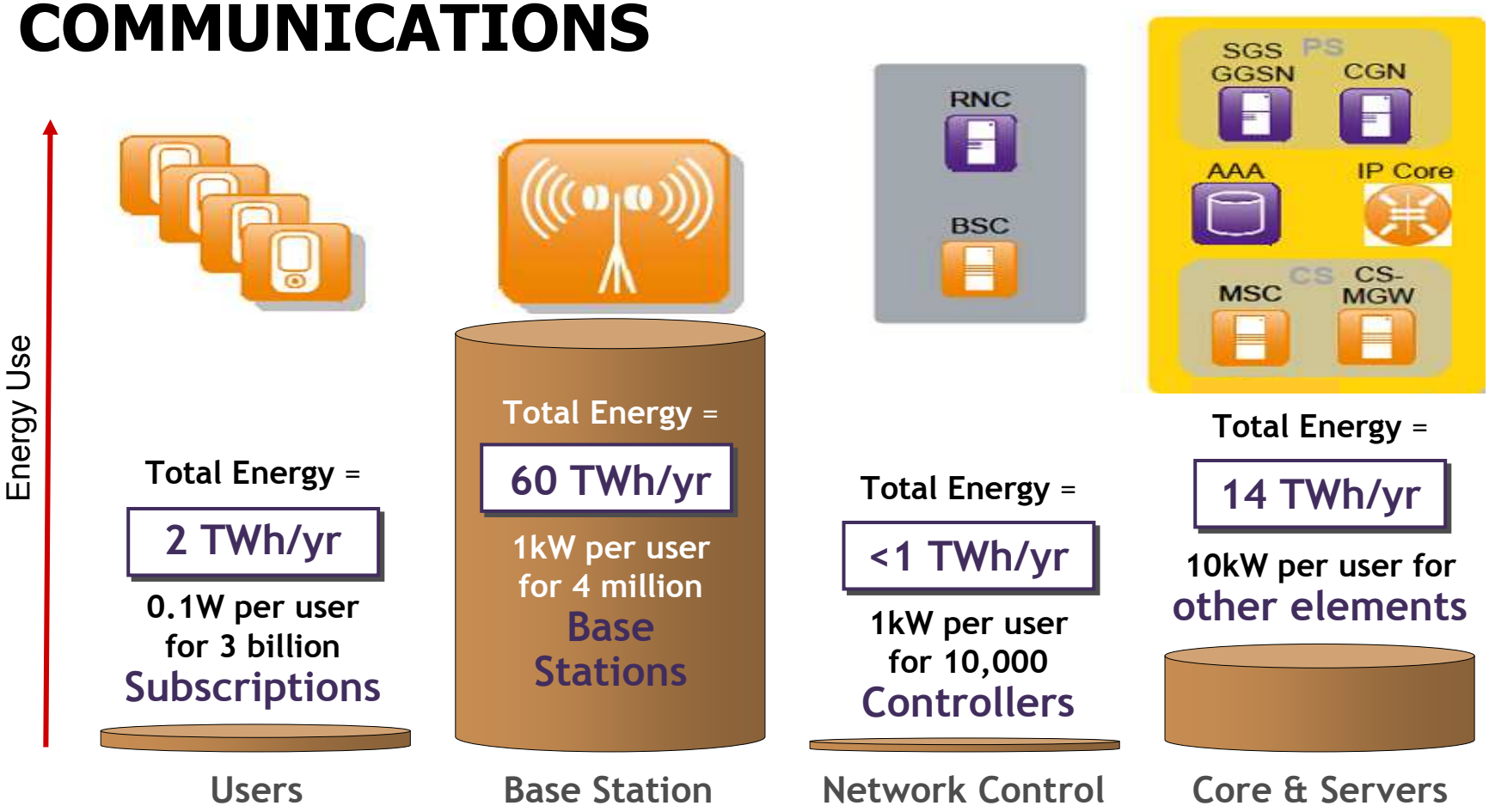
HOLISTIC NETWORK PERSPECTIVE



End-to-end, life cycle approach toward intelligent, energy-efficient networks

Wireless and Mobile Communications

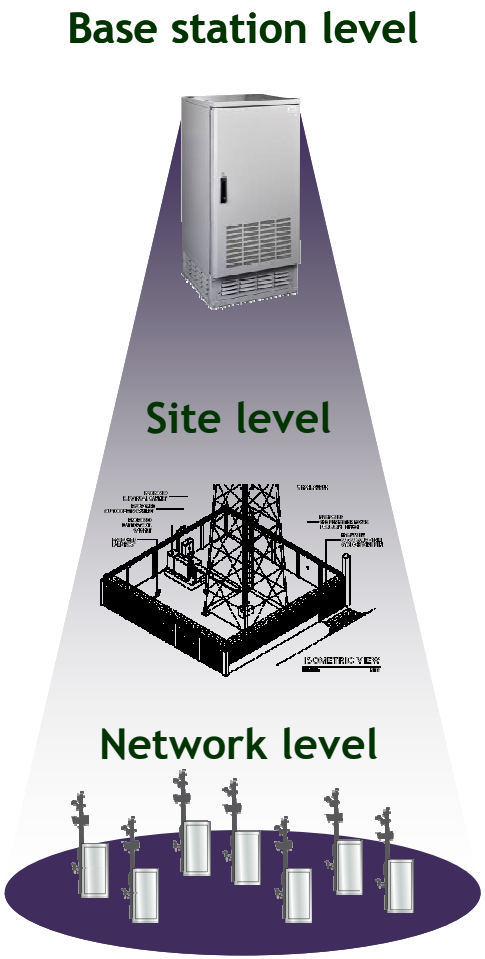
POWER CONSUMPTION OF MOBILE COMMUNICATIONS

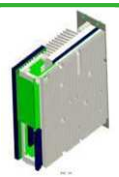
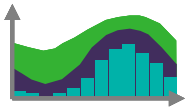


The greatest opportunity to reduce energy consumption is to improve base stations

Based on: ETSI RRS05_024, NSN

IMMEDIATE OPPORTUNITIES



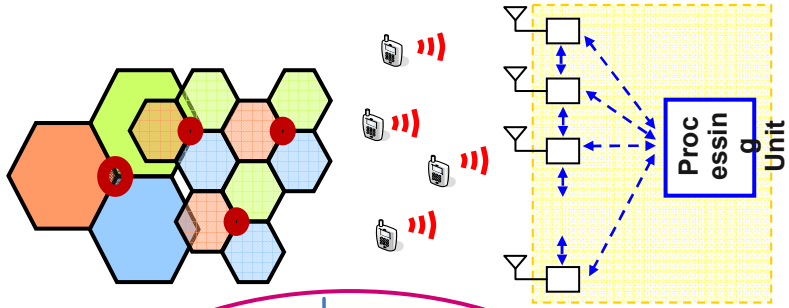
Hardware integration		Multi-carrier power amplifier	-30%
Dynamic software		Dynamic power save	-30%
No air con outdoor		Direct cooling	-50%
No feeder		Remote radio head	-25%
High and focused coverage		Smart antenna	-40%

IS THAT ENOUGH???

GREEN WIRELESS RESEARCH DIRECTIONS

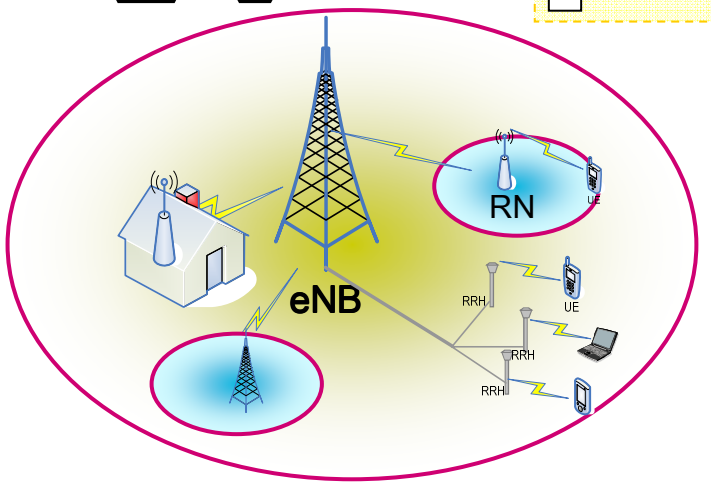
Green Air Interface

- Large Scale Antenna Systems GreenTouch
- Very High Bandwidth GreenTouch
- Bandwidth and Capacity Adaptation



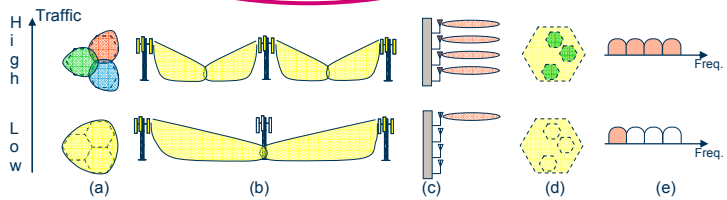
Network Architecture & Mgmt

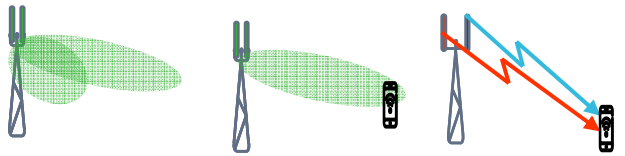
- Dynamic Management for Energy Efficiency
- Small Cells, Relays and Repeaters, HetNets
- Beyond Cellular Green GreenTouch
- Energy Efficient C-RAN
- Energy Efficiency Evaluation Framework



Base Station Hardware

- Ultra Low-Power Base-Station on a Chip
- Load Adaptive Transceivers
- High Efficiency RF-Power Amplifiers
- Renewable Energy Powering
- New Architectures such as lightRadio™





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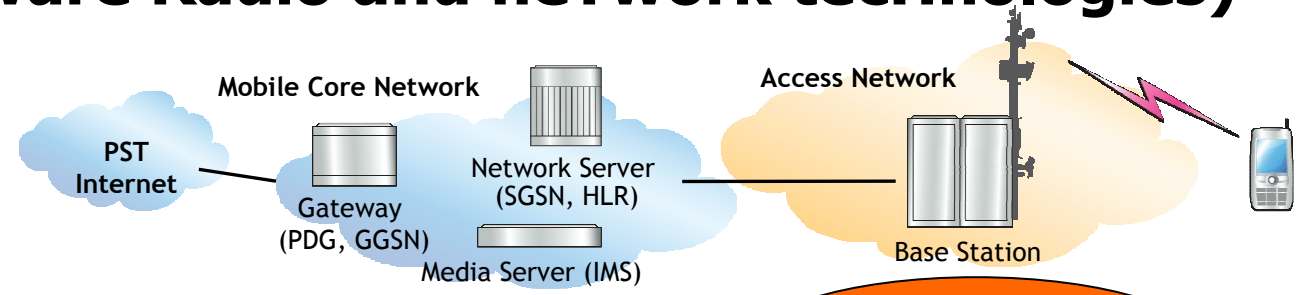
EU FP 7 PROJECT EARTH
(Energy Aware Radio and neTwork tecHnologies)

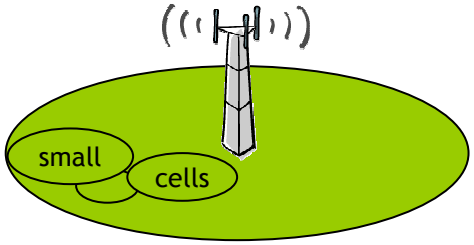
Energy Aware Radio and neTwork tecHnologies



70-80% of overall energy consumption

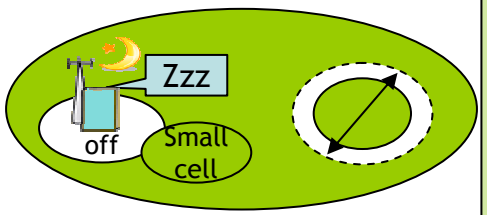
GOAL: SAVE 50% POWER IN LTE-BASED ACCESS NETWORKS

Deployment



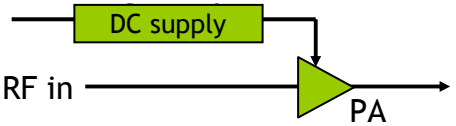
Small Cells with Overlay Macro Cell

Network Management



Dynamic operation; Sleep modes, Bandwidth Adaptation,…

Components

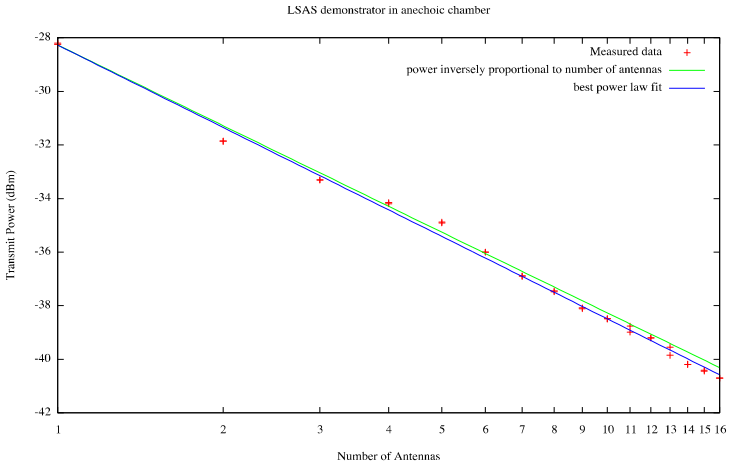


Power Amplifier & Transceiver, Load-adaptive Hardware

https://www.ict-earth.eu

LARGE SCALE ANTENNA SYSTEM

Measured transmit power is inversely proportional to the number of antennas:

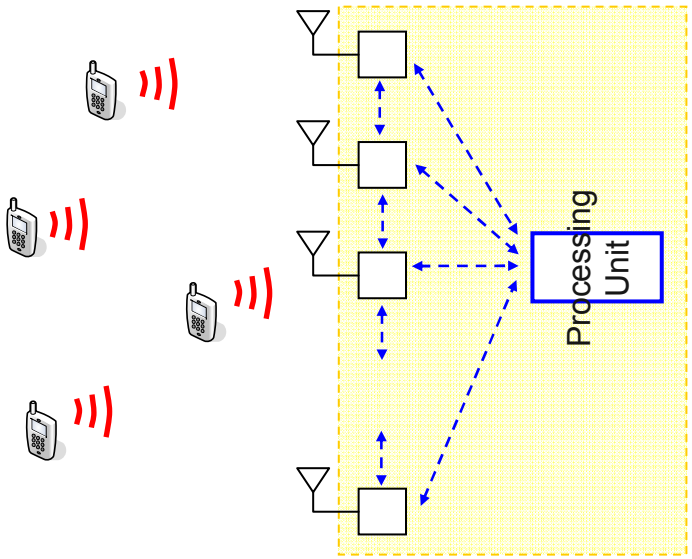


- ***Beam-forming for energy efficiency, not capacity***
- ***First GreenTouch technology demonstration***

APPLICATION SCENARIOS

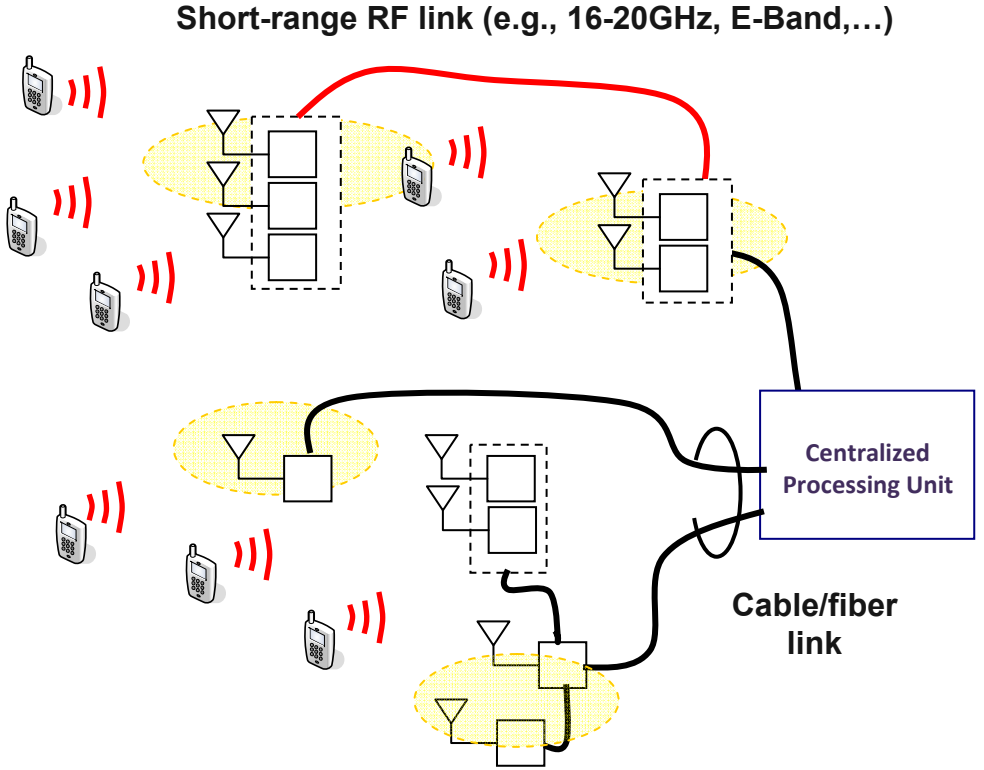
GreenTouch

Massive Co-located Antennas



Marzetta, T. L., IEEE Trans Wireless Communications, Nov 2010

Spatially Distributed Antennas



- ***100's or 1000's of antenna elements***
- ***'Power amplifiers' operating at micro-Watt levels***

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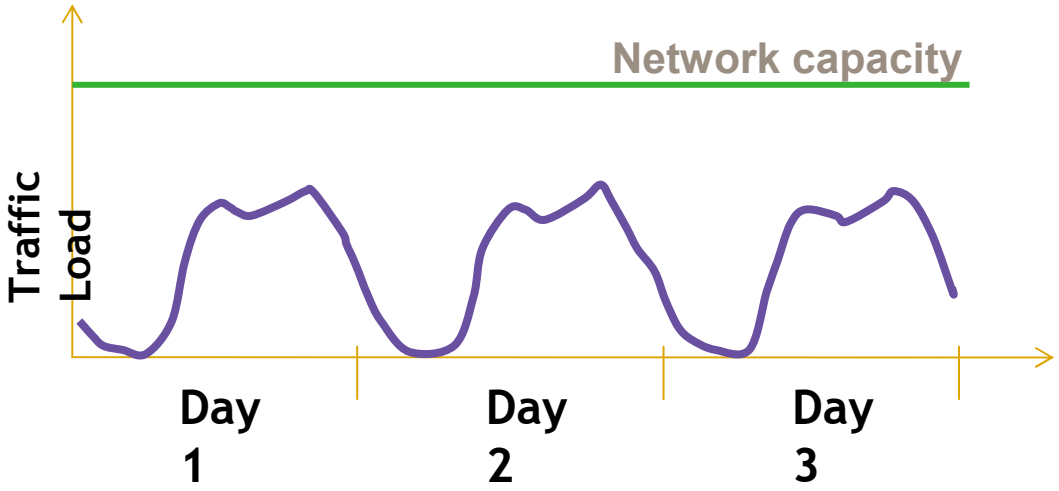
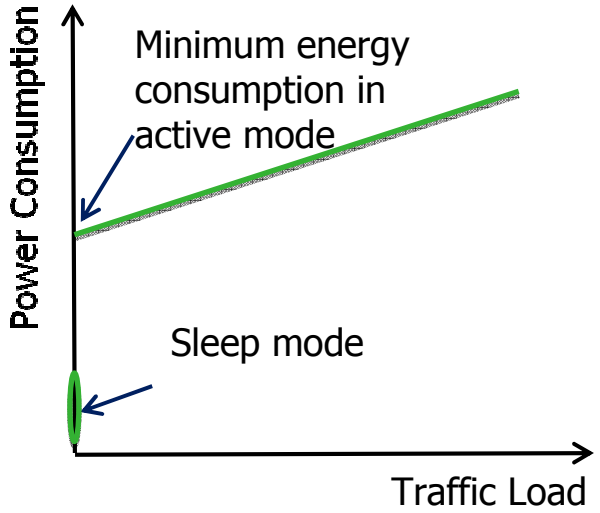
BEYOND CELLULAR GREEN GENERATION (BCG²)





- Wireless access networks are dimensioned for estimated peak demand using dense layers of cell coverage
- Traffic varies during the day
- Energy consumption is almost constant – Due to the power consumed by signaling

Alcatel·Lucent HUAWEI SAMSUNG orange TNO TECHNISCHE UNIVERSITÄT DRESDEN INRIA POLITECNICO DI MILANO

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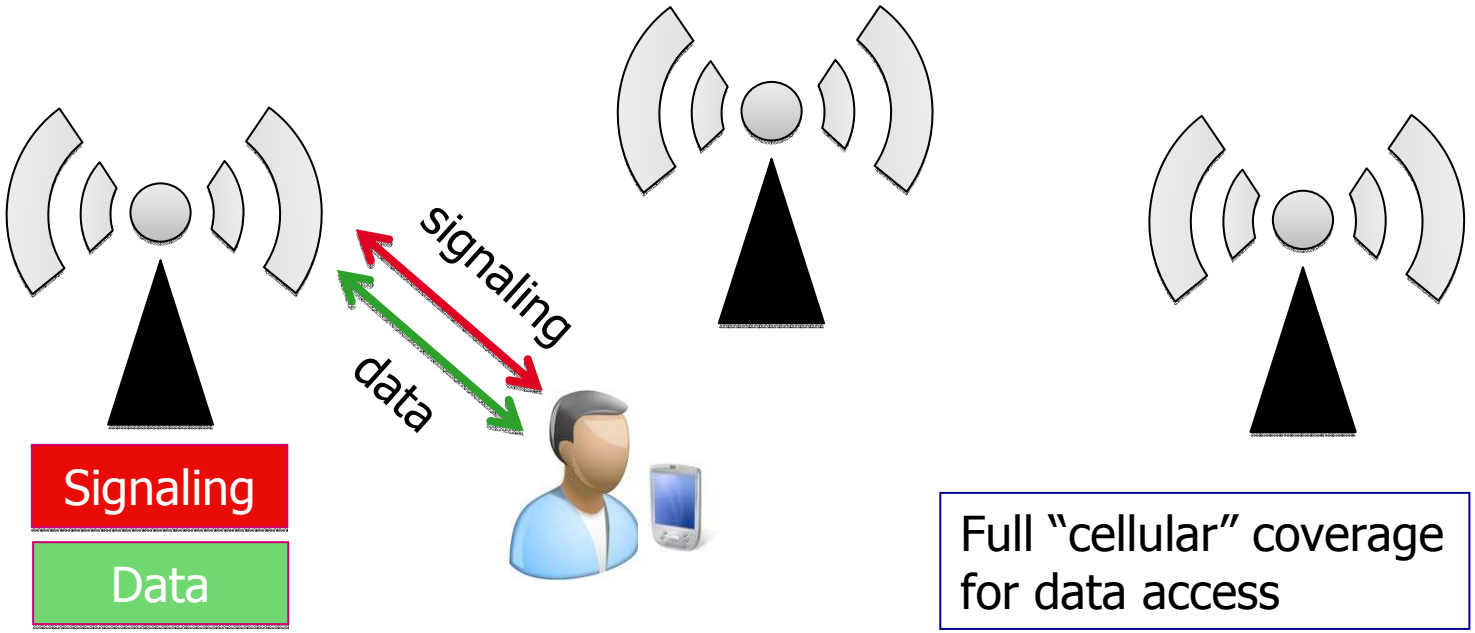
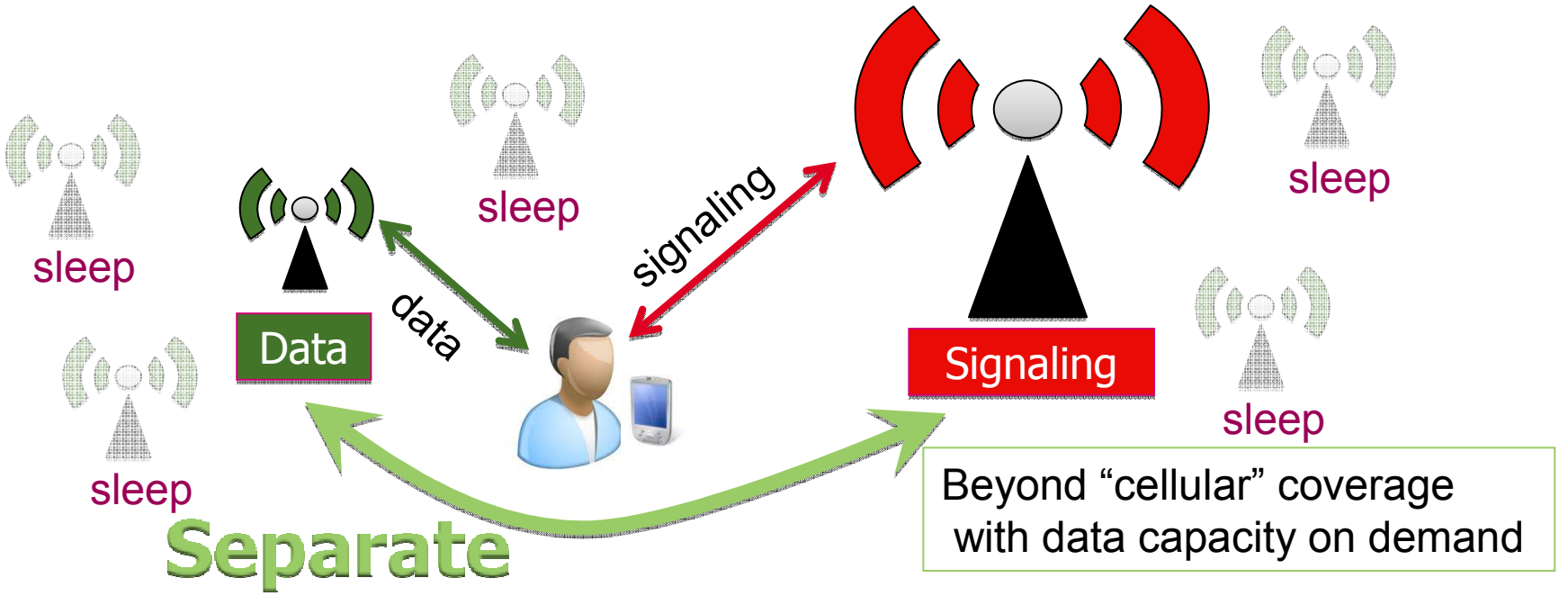
TRADITIONAL CELLULAR ARCHITECTURE



Limitation of traditional cellular architecture:

- Continuous and full coverage for data access
- Limited flexibility for energy management
- High energy consumption also at low traffic load

BCG² ARCHITECTURE



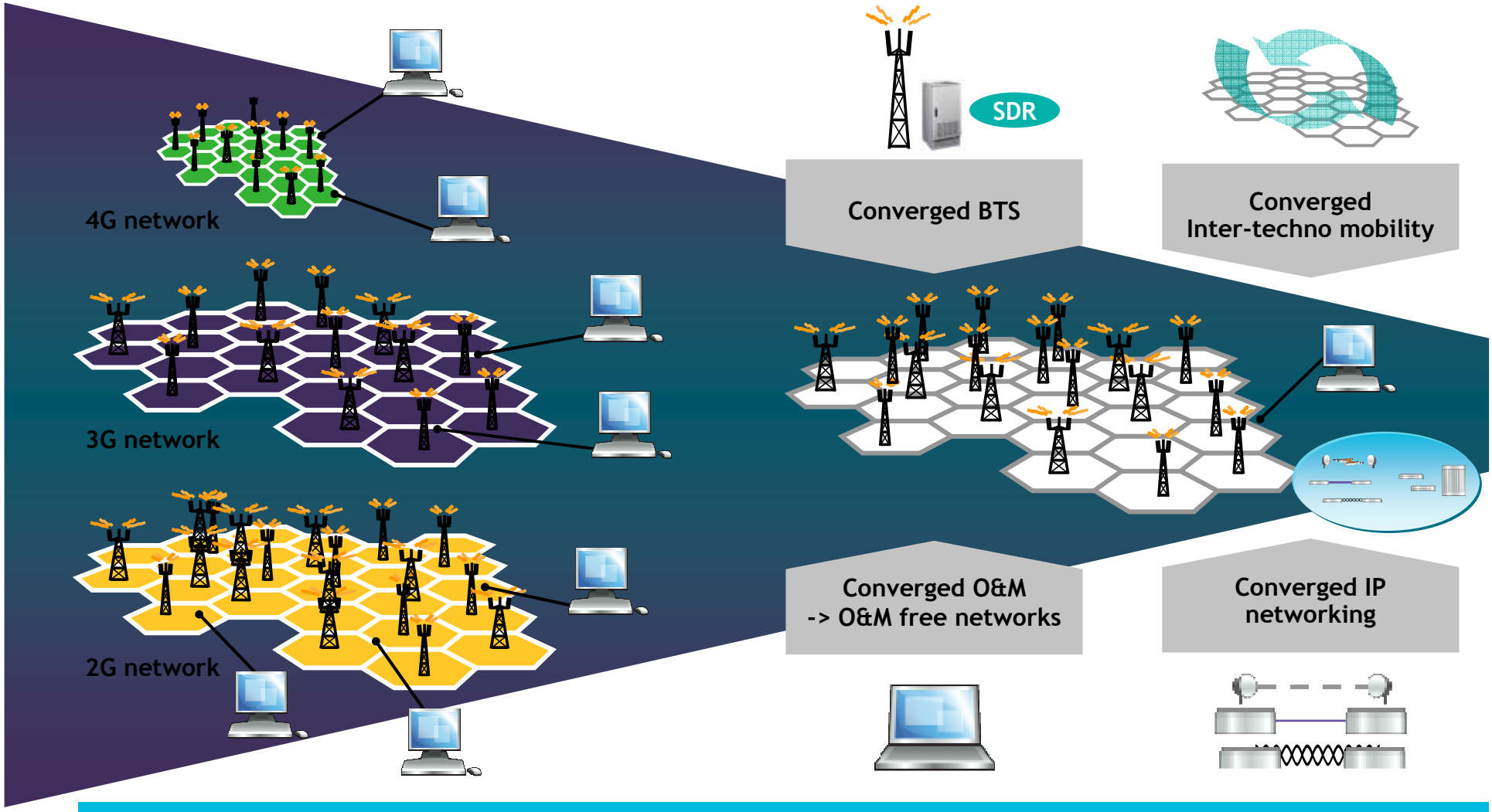
Opportunities for sustainability:

- 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

SOFTWARE DEFINED WIRELESS NETWORKS

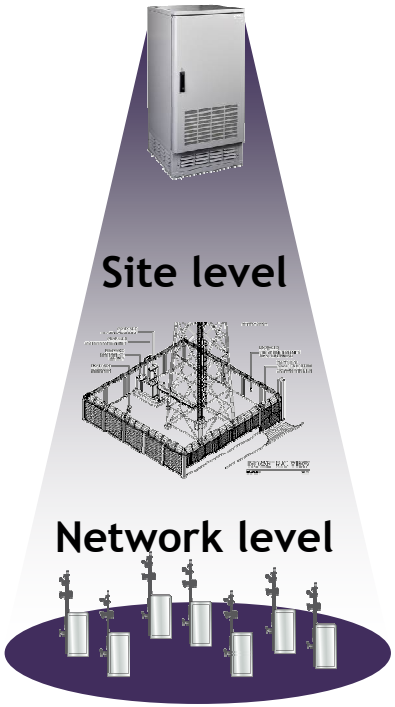


SDR: Avoiding the energy/waste that new hardware manufacturing would require

GREEN WIRELESS ACCESS STRATEGY

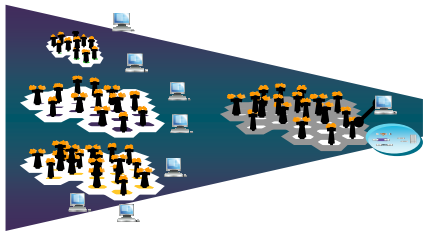
Energy efficiency with holistic strategy

Base Station Level



Technology evolution with less hardware

Converged RAN solution



- Converged BTS, mobility, transport, O&M
- Leveraging multitechno SDR modules to avoid manufacturing of new hardware

1. Production
2. Usage
3. End-of-Life

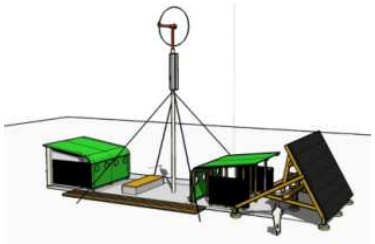
Alternative energy at industrial scale

Alternative Energy Sources

Telecom expertise and energy eficiency

Selecting the best alternative energy solutions

Tested and integrated on our unique lab and trial platform



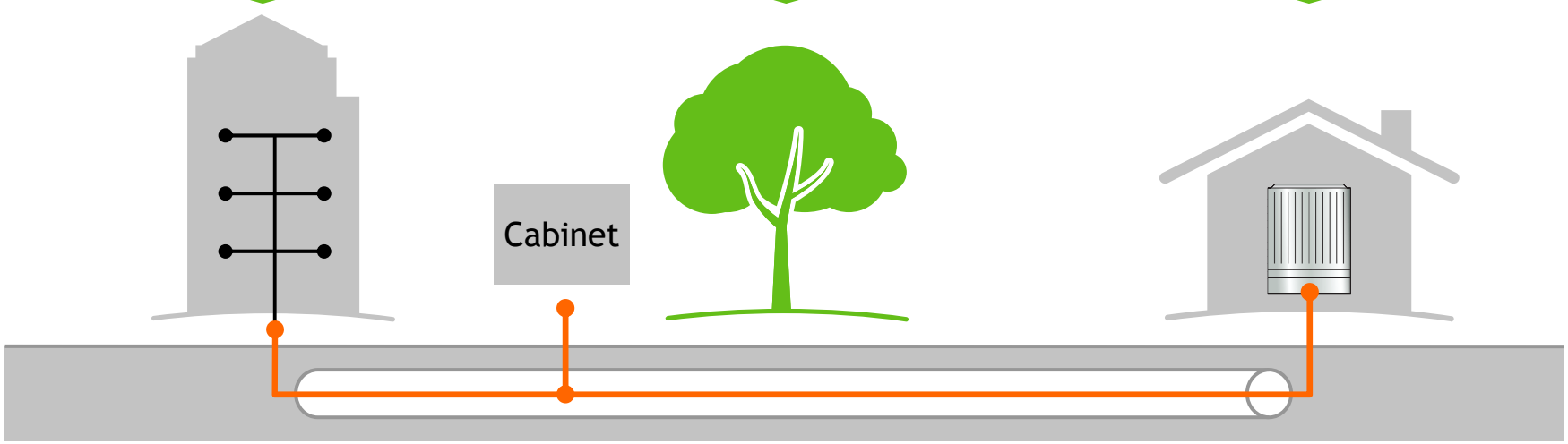
Delivered in volumes with consulting, transformation at full network level

Innovate

Wireline and Fixed Access Networks

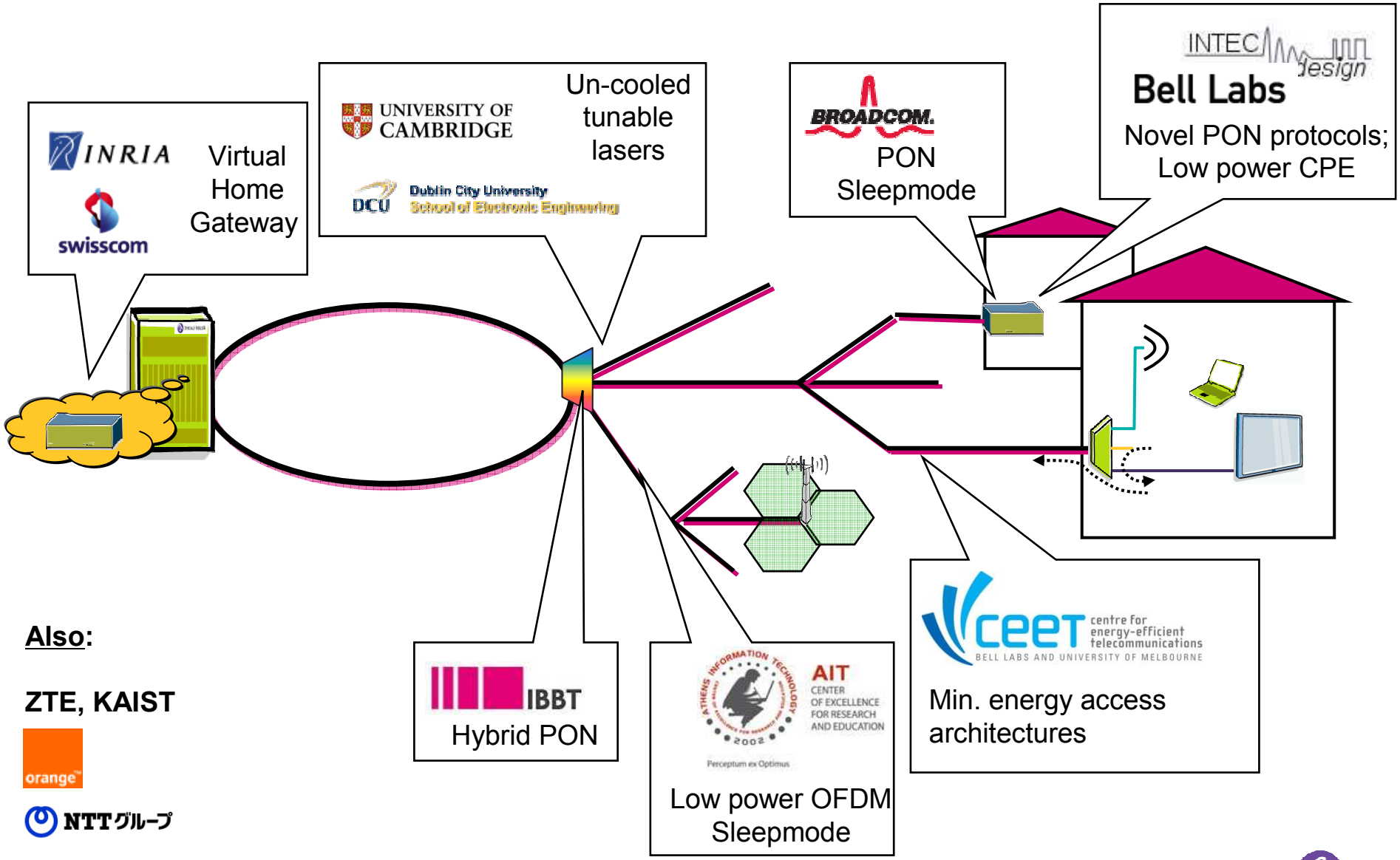
ECO-SUSTAINABLE FIXED ACCESS NETWORKS

Customer premises	Outside plant	Network equipment
▪ Passively cooled remotes ▪ Sleep modes	▪ Duct sharing ▪ Micro trenching ▪ Heat exchangers	▪ Green DSL technology ▪ Distributed DSLAM ▪ Green GPON



GREEN WIRELINE ACCESS RESEARCH

GreenTouch



Also:

ZTE, KAIST

orange

NTTグループ

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BIT-INTERLEAVING PASSIVE OPTICAL NETWORK (Bi-PON)

- The Problem: In current FTTH architectures, all data is processed but 97% is unused
  - With FTTH expected to nearly double over the next five years—to 142 million subscribers worldwide—energy consumption is a major concern.

- GreenTouch Solution: New Bit-Interleaving Passive Optical Network (BI-PON) technology
  - New FTTH protocol that consumes 10x less power than currently available technologies
  - Next major leap in optical technologies, expected to be a necessity as electronic processing will increase with the next-generation 40GPON systems expected by 2015
  - Enable power reduction equal to taking 3 million cars off the road

- Second major milestone toward achieving the GreenTouch goal

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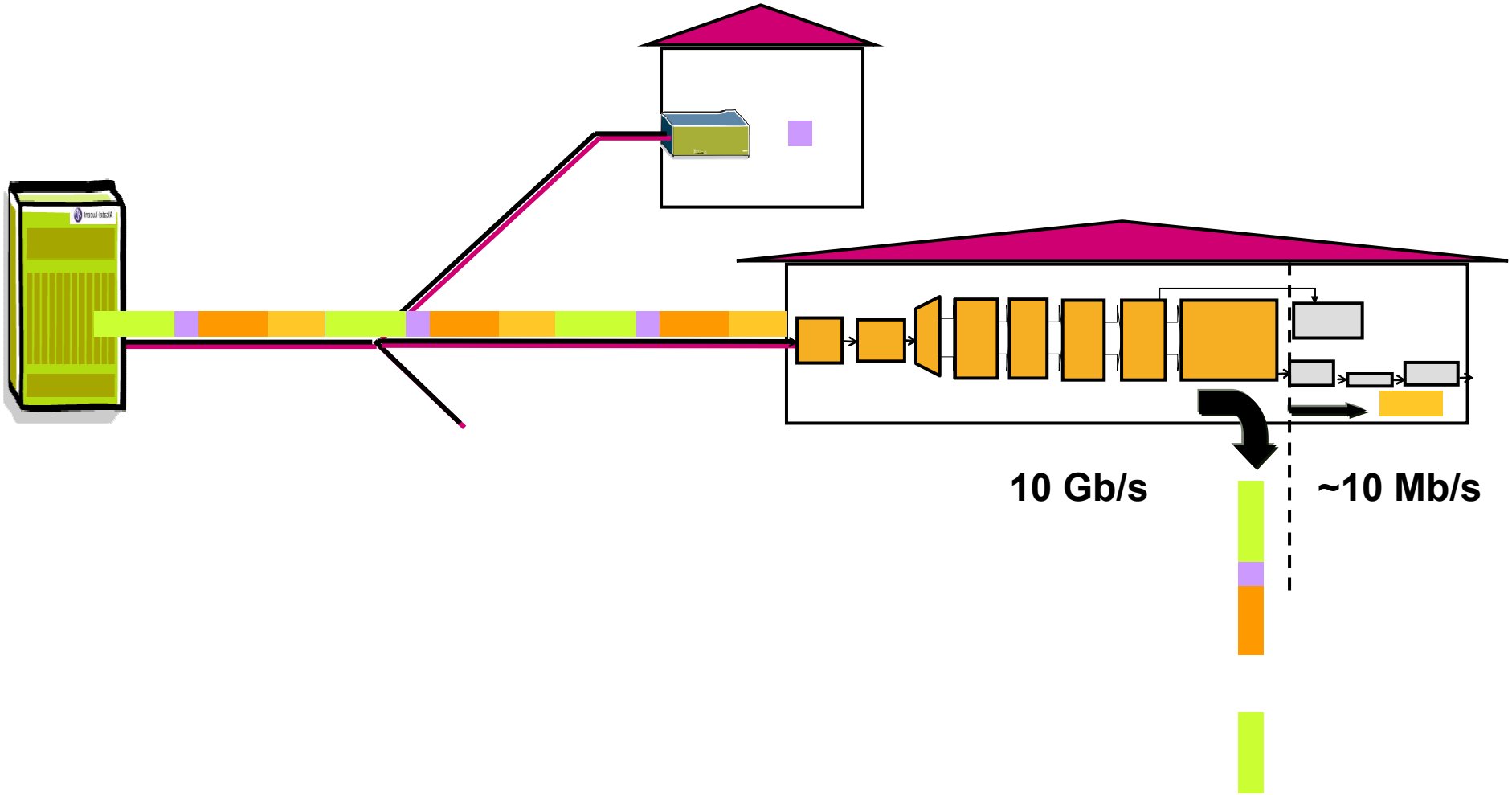
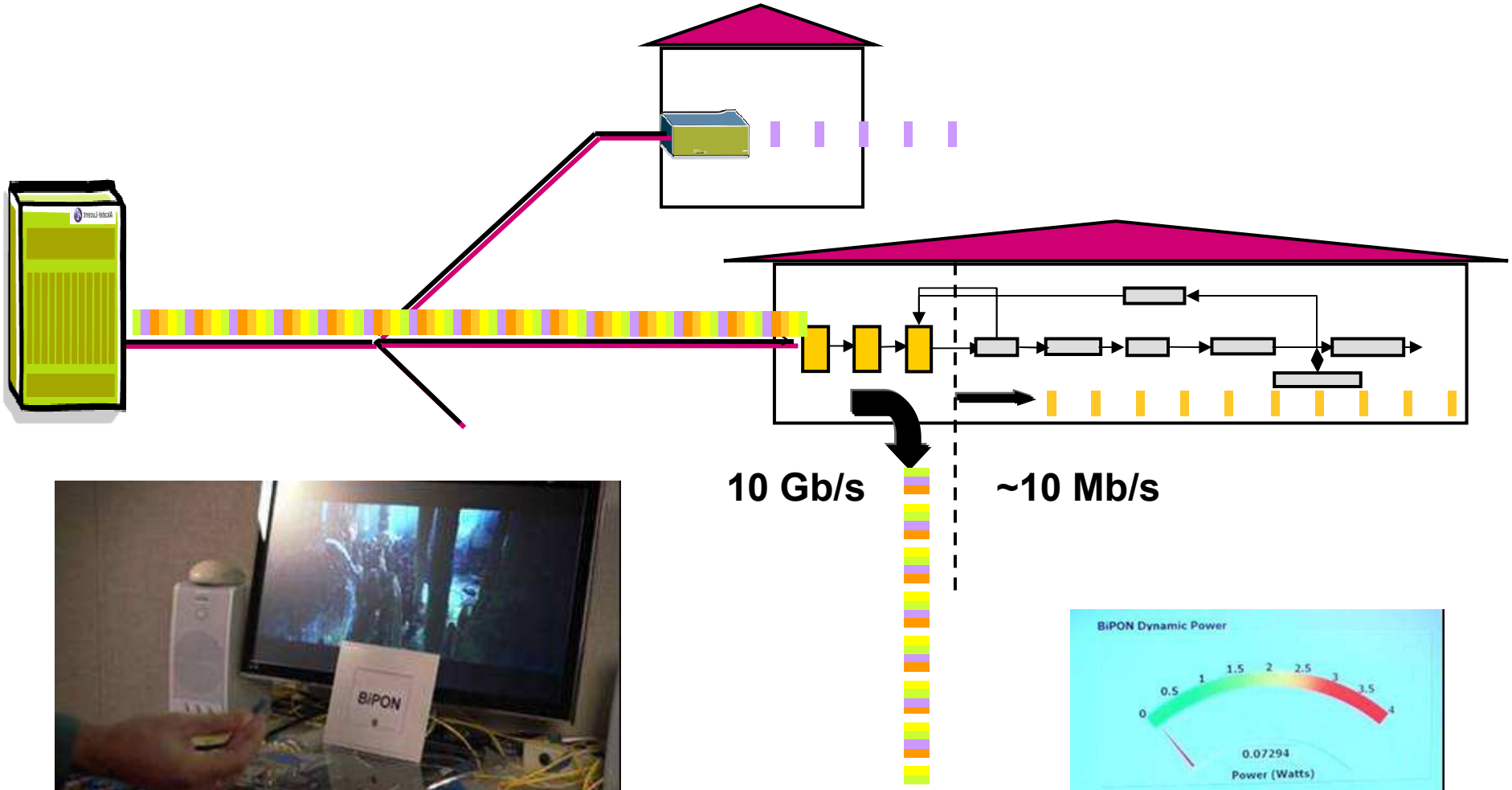
STANDARD XG-PON

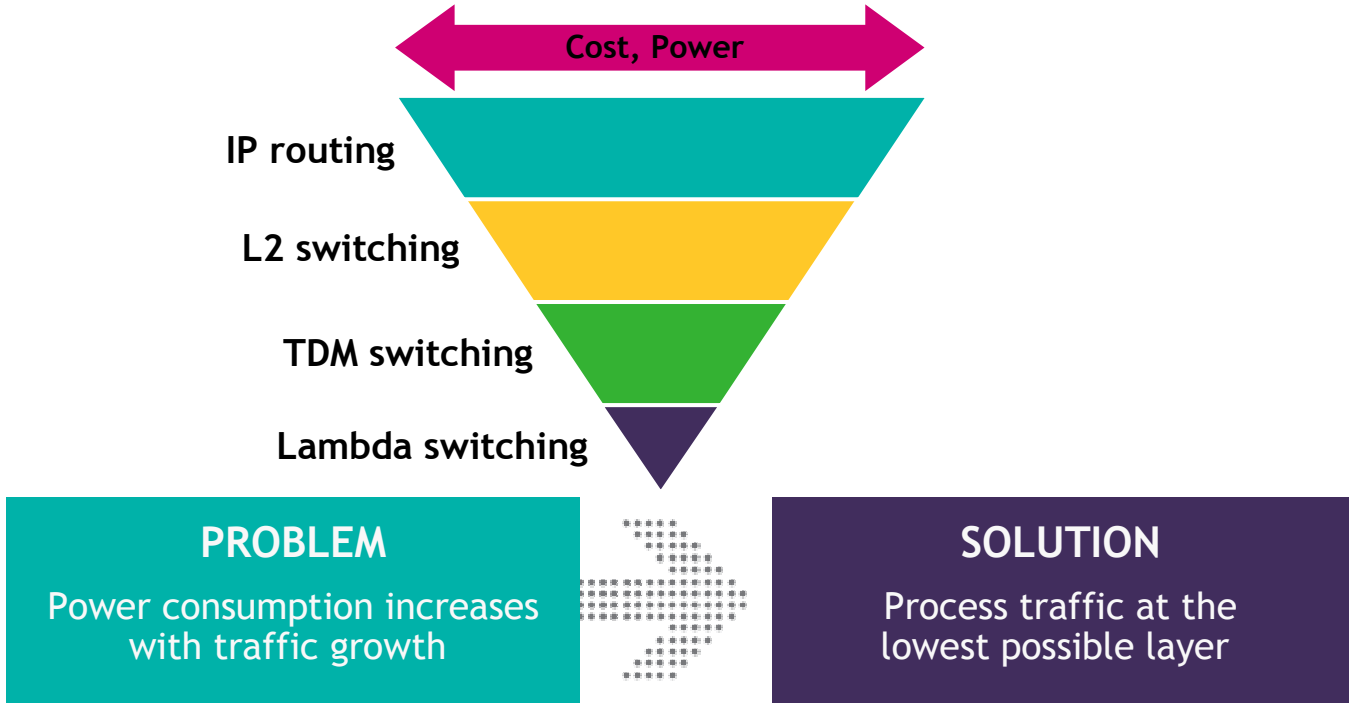


BIT-INTERLEAVING PON DELIVERS >10x BETTER EFFICIENCY



Core Networks

PROCESS TRAFFIC AT LOWEST LAYER POSSIBLE



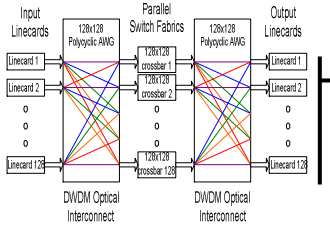
Resource optimization reduces power consumption
Cross layer intelligence sends traffic to the lowest consumption layer

GREEN CORE NETWORKS RESEARCH

Bell Labs Project

GreenTouch Project

Massively Scalable Router Architecture



Packet Timescale Rate Adaptation; Active Queue Management

ZeBRA: Zero-Buffer Router Architecture

REPTILE: Router Power Measurements

Dynamic Optical Bypass

Energy Efficient and TCO-Optimal IP over WDM Network Topology

SCORPION: Si-Photonic Interconnects and Single-Chip Linecard

Core routers

Service routers

OTN/photonic switches

Service routers

Data Centers

Internet

STAR: Switching and Transmission

EFICOST: Energy Efficient High Capacity OFDM Signal Transmission

PANDA: Power Aware Network Design and Auto-Configuration

Energy-Efficient Flow Control

OPERA: End-to-End Resource Allocation

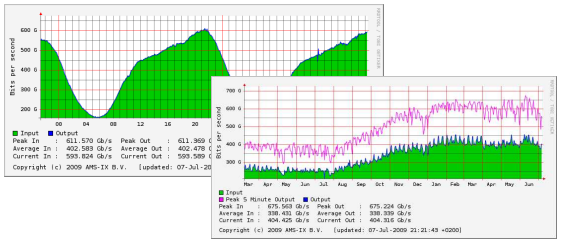
HALF-MOON: Highly Adaptive Layer for Mesh On-Off Optical Networks

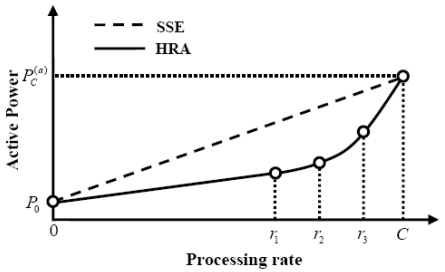
SEASON: Service-Energy Aware Sustainable Optical Networks

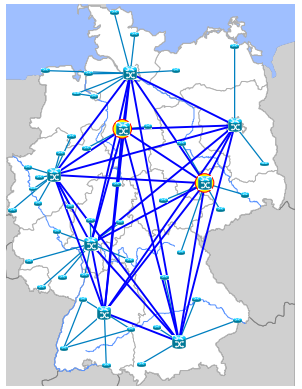
TIGER: Time for a Greener Internet

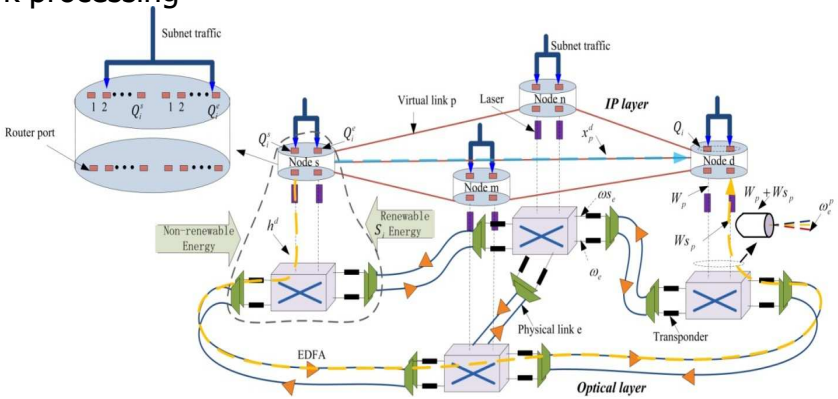
JOINT OPTIMIZED IP OVER OPTICS NETWORK

- **Main ideas:**
  - End to end optimum architectures across physical, network and transport layers
    - Optimal network topologies
  - Dynamic resource allocation strategies at different time scales
    - Sleep modes for packet processors, buffers, optical amplifiers and transponders
    - Dynamic sizing of buffers
    - Rate adaption
    - Routing and scheduling of links
    - Protection and restoration
  - Extension to applications and services
    - Optimal location for content caching and in-network processing
- **Open issues:**
  - Overall energy efficiency gains
  - Control timescales
  - Network stability
  - Equipment reliability





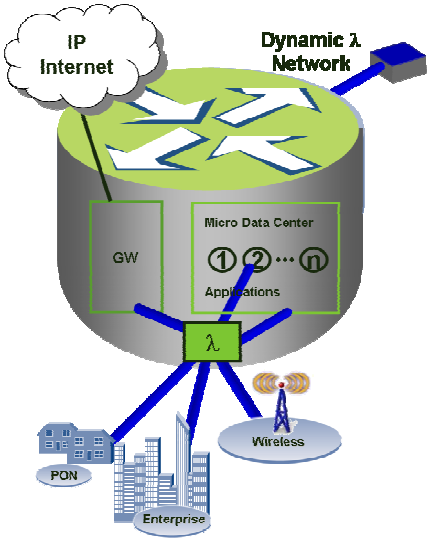


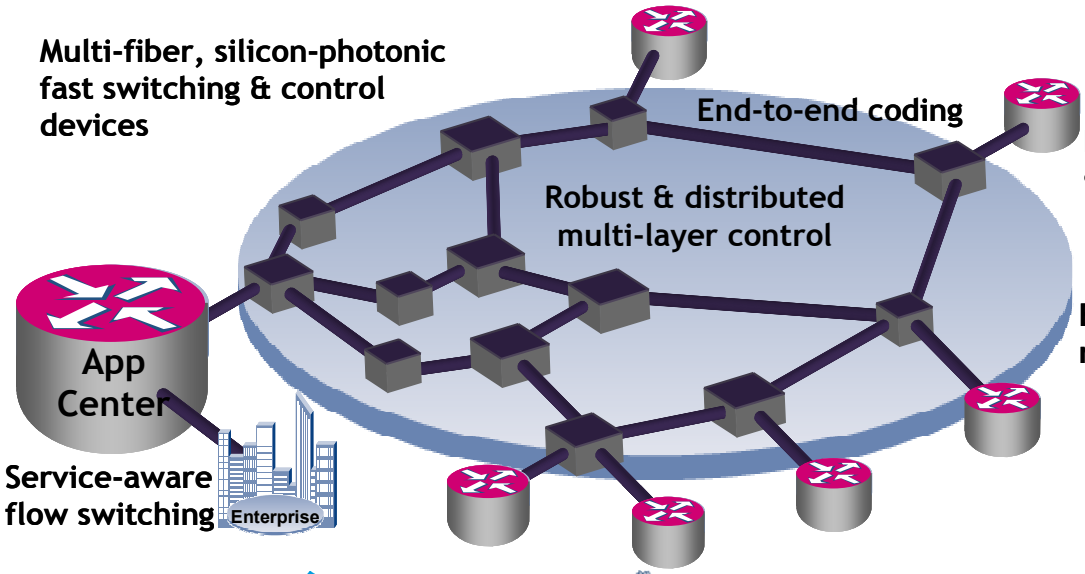


SERVICE ENERGY AWARE SUSTAINABLE OPTICAL NETWORKS

GreenTouch

- Clean-slate network design project focusing on a networked platform of micro data centers:
  - Maximum energy efficiency through awareness of service requirements
  - Targeted for services with high bandwidth
  - Virtualization and workload migration
  - Tracking available renewable energy sources





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

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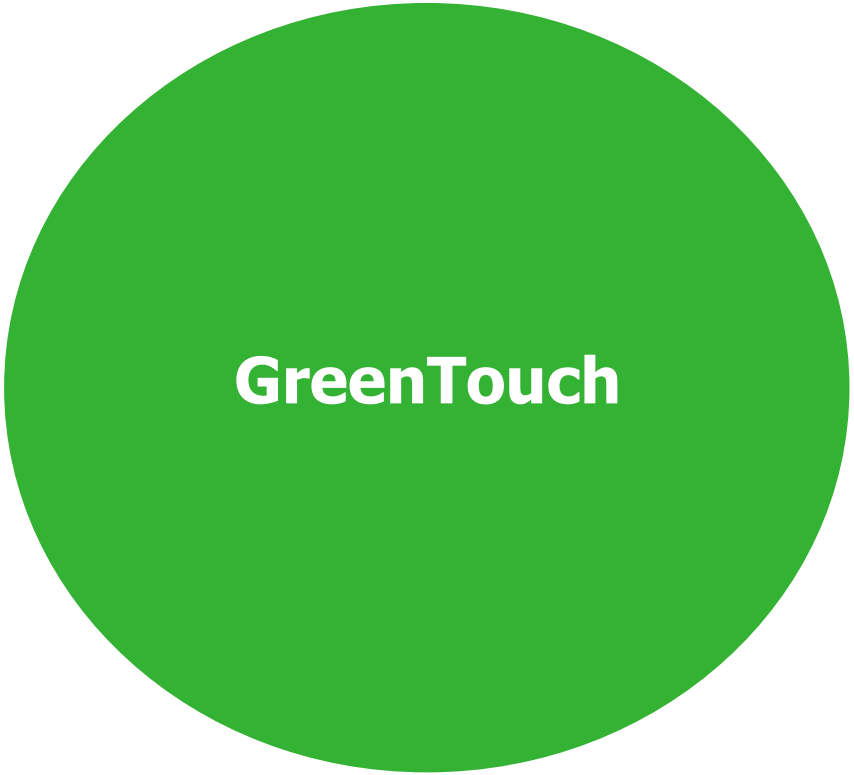

GREENTOUCH™ (www.greentouch.org)

- **Global research consortium** representing industry, government and academic organizations
- Launched in May 2010
- Focus on **sustainability** and growth
- **Holistic** and **ambitious**: Goal of 1000x
- **59 member organizations**
- **300+ leading scientists**
- Recognized by the **World Economic Forum** as an industry-led best practice toward sustainability

It takes an ecosystem

- 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
- Creating a **new innovation model** for sustainability

DELIVER ARCHITECTURE, SPECIFICATIONS AND SOLUTIONS AND DEMONSTRATE KEY TECHNOLOGIES TO INCREASE NETWORK ENERGY EFFICIENCY BY A FACTOR 1000 COMPARED TO 2010

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WHY NETWORK ENERGY EFFICIENCY?

Green Services

Increase

Growth

Bits per second

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

Watts

Reduce

Reduced
Carbon
Footprint

Makes both Environmental and Economic Sense

SOME RESEARCH PROJECTS…

GreenTouch™

Beyond Cellular – Green Mobile Networks — Fondazione Politecnico di Milano

Virtual Home Gateway — swisscom

Optimal End-to-End Resource Allocation — UNIVERSITY OF LEEDS

Service Energy Aware Optical Networks — Columbia University in the City of New York

Green Transmission Technologies — HUAWEI

Minimum Energy Access Architectures — ceet centre for energy-efficient telecommunications

Single-Chip Linecards — Bell Labs

Large-Scale Antenna Systems — imec

Highly-Adaptive Layer Mesh Networks — Bell Labs

Massive MIMO — SAMSUNG ADVANCED INSTITUTE OF TECHNOLOGY

25+ Projects

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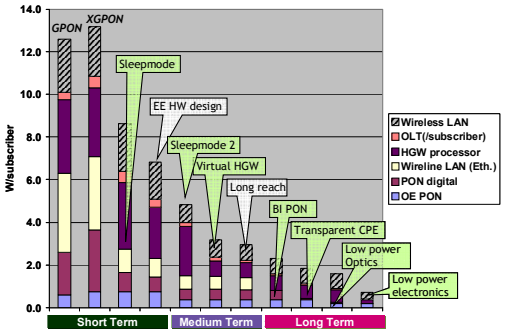
GREENTOUCH STATUS: WHERE ARE WE?

- Over 15 research programs and 25 research projects underway
  - 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 in wireless and fiber-to-the-home technologies
- Services, Policies and Standards working group established as interface to relevant bodies and external stakeholders
- Establish and define common reference architecture and roadmap with strategic research directions



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CONCLUSIONS

- ICT networks are growing rapidly
- ICT and research communities are organizing to address challenges
- Promising research directions and initial results have been obtained
- Need for an end-to-end network architectural approach
- Sustainable networks of the future should consider the entire energy ecosystem
- More work remains!

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AT THE SPEED OF IDEAS

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