Energy efficiency for transport networks - main achievement from ICT STRONGEST

TREND workshop

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Outline

- **What is STRONGEST**
- **Energy efficiency: dirivers**
- **Energy efficiency: the STRONGEST solution**

STRONGEST at a Glance

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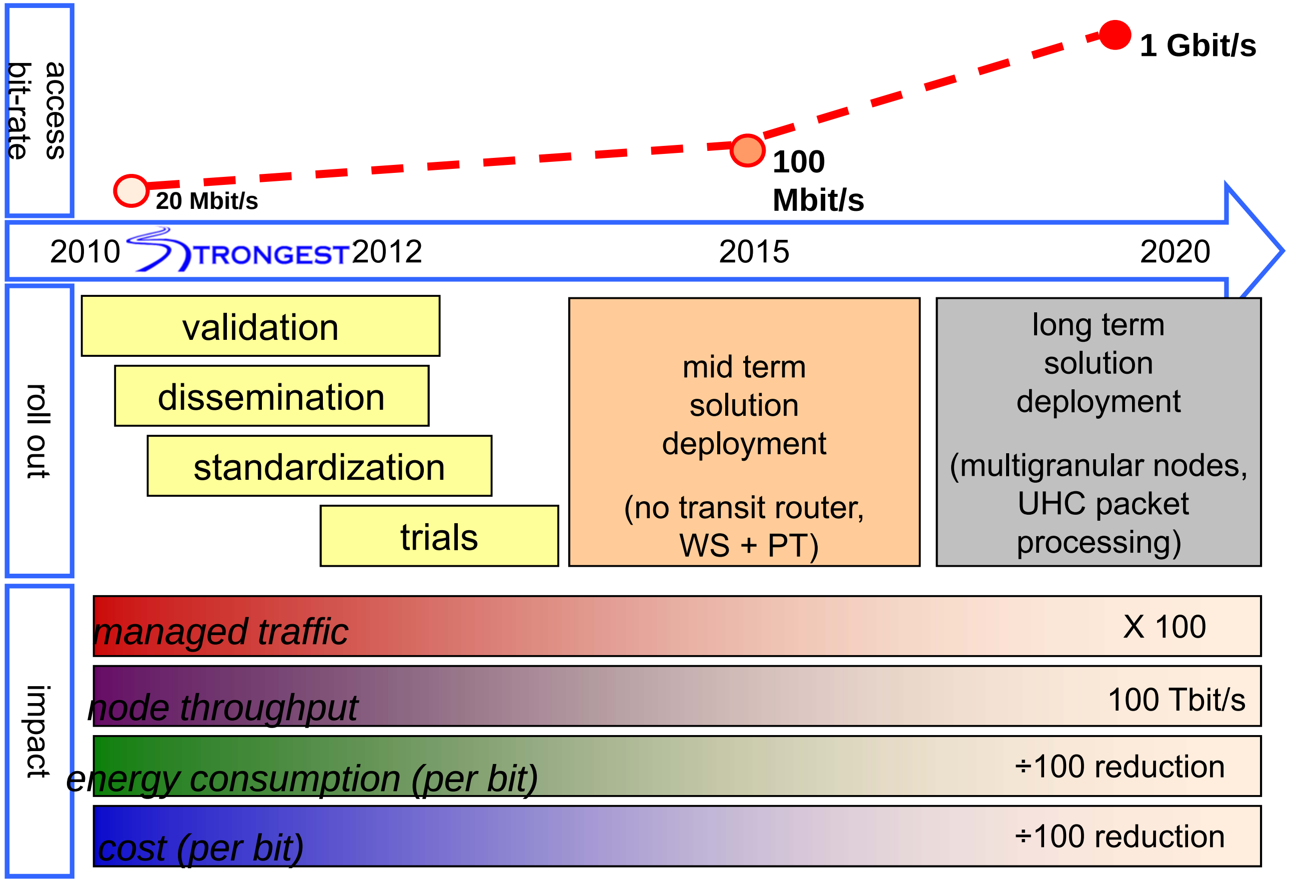
Deployment and impact



Strengthen the position of European industry in the field of Future Internet and reinforce European leadership in optical networks

Make advanced services more affordable for citizens and more respectful for environment

Facilitate the creation of global standards and foster interoperability

Create wider market opportunities from new classes of applications taking advantage of convergence

Accelerate the uptake of next generation networks and service infrastructures

What is innovative in STRONGEST?

- leveraging on transport network architecture rather then on mere equipment technology
- data plane architecture eliminating transit routers (IP equipment only at the edge)
- multi-granular hybrid node architecture with integrated control plane
- control platform (integrating RACS and H-PCE) implementing a set of control functions in complex scenarios with virtualized resources
- OAM functions allowing detection of SLA violations in a complex scenario

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Energy efficniency among main objectives

To design and demonstrate an evolutionary ultra-high capacity multilayer transport network**, compatible with Gbit/s access rates, based on optimized integration of optical and packet nodes, and equipped with a** multi-domain, multi-region control plane**.**

This network will offer:

- **High** scalability
- Flexible **bandwidth management**
- **Guaranteed** end-to-end quality of service **and** survivability
- **Increased** energy efficiency
- **Reduced** total cost of ownership

Parameters to be evaluated and optimized

Network throughput [Tbit/s]
Node throughput [Tbit/s]

Managed connections [n/s]

Provisioning time [s]

End-to-end QoS in complex networks

Restoration time [ms]
Mean unavailability [min/y]

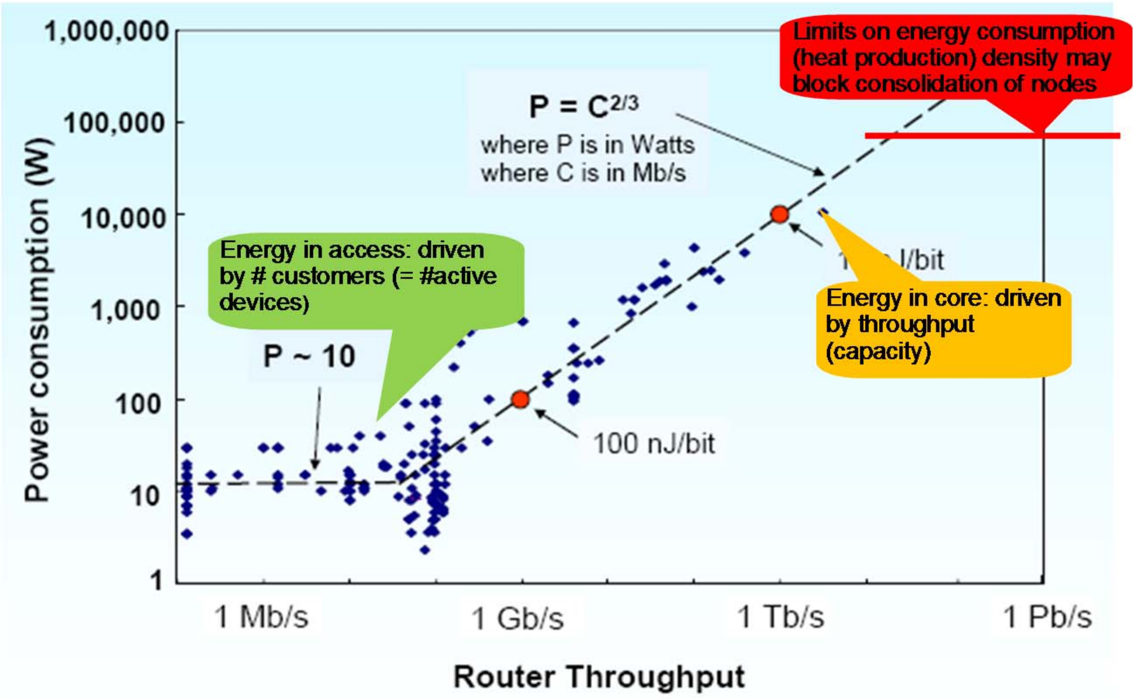
Power consumption [W/bit/s]
Energy consumption [J/bit]

Investments [€/Gbit/s]
Operational expenditures [€/Gbit/s]

Transport network consumption is an issue?

- **In telecommunications networks the vast majority of the power consumption can be attributed** today **to** mobile and fixed line access **networks.**
- **Emissions problems in access networks are being reduced because:**
  - **The current trend is to replace the copper based technologies by fibre.**
  - **DSLAMs are replacing local telephonic switches**
  - **The access emissions are slightly dependent on bit-rate**
- **In the** near future **transport networks emissions will become increasingly more important and router power consumption bottleneck will be reached**

Routers – power consumption bottleneck

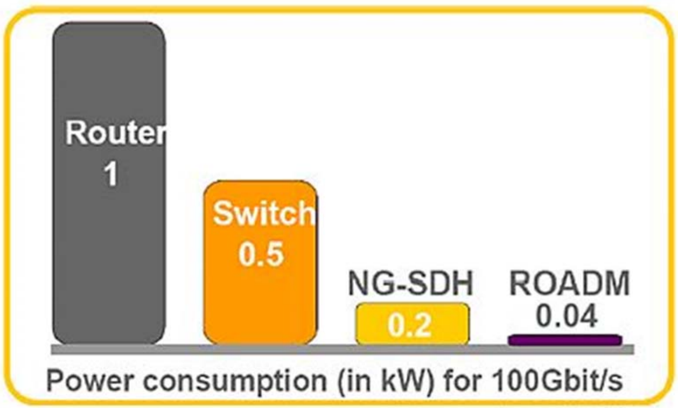


(From: M. Pickavet et al. "Energy footprint of ICT", METI, 2006, Nordman, 2007)

Currently: Access is dominating overall energy consumption

In future:

- Core will become increasingly important → innovation needed to keep this under control
- Feasibility limits may be reached (growing traffic volumes & more node consolidation)
  → innovation needed to stay well below these limits – even avoid further growth of energy



Source: NSN 2008

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The importance of metrics

Important to adopt a convenient, insightful framework to measure energy efficiency

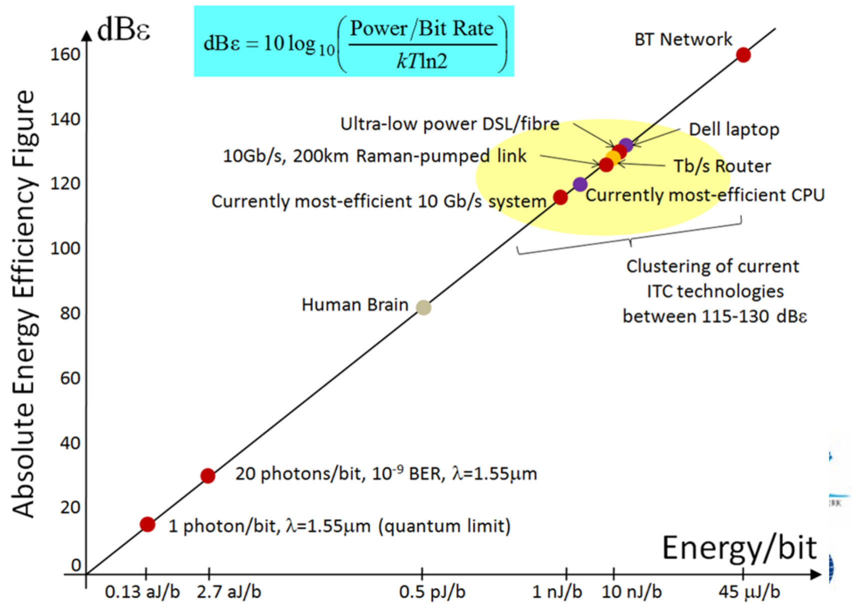
- dBε is an absolute energy efficiency metric
- kW/Mbit/s is a instantaneous power consumption
- J/GBytes is absolute energy dissipation metric

$$dB\varepsilon = 10\log_{10}\left(\frac{\text{Power}/\text{Bit Rate}}{kT_{LO}\ln 2}\right)$$

Boltzmann's constant k=1.381x10^{-23} J/K

Absolute temperature T=300 K

	Power	Effective bit-rate	Energy/bit [J/b]	dBε
BT Network	1 GW	22 Tb/s	45x10^{-6}	162.0
Dell laptop	80 W	1.87 GHz (clock)	42.8x10^{-9}	131.7
Ultra-low power DSL/fibre	165 mW	10 Mb/s	16.5x10^{-9}	127.6
Tb/s Router	10 kW	1 Tb/s	10x10^{-9}	125.4
200 km Raman-pumped link	60 W	10 Gb/s	6x10^{-9}	123.2
Currently most-efficient CPU	2.8 W	1 Gflops	2.8x10^{-9}	119.9
Currently most-efficient 10 Gb/s system	10 W	10 Gb/s	1x10^{-6}	115.4
Human Brain (T=310 K, or 37°C)	20 W	40 Tb/s	0.5x10^{-12}	82.3
20 photons/bit, 10^{-9} BER, λ=1.55μm	25.6 nW	10 Gb/s	2.56x10^{-18}	29.5
1 photon/bit , λ=1.55μm (quantum limit)	1.28 nW	10 Gb/s	0.128x10^{-18}	16.5



10 Independent Ways to Cut Energy Consumption

4 Main Areas to Concentrate Upon, each with *independent* approaches:

A. **Improved inherent energy-efficiencies as offered by *electronics technologies***

(1) **More efficient CMOS technologies**

(2) **High temperature operation of ICs**

B. **More sophisticated *management and exploitation of network resources***

(3) Source coding & caching

(4) Multi-layer traffic engineering (MLTE),

(5) Powering down, sleep/idle modes and burst-mode operation.

C. **The inherent energy efficiencies as offered by *optics technology solutions***

(6) Optical bypass

(7) Coherent detection

(8) Polarisation multiplexing.

A. **More *environmentally sustainable approaches* to network design such as**

(9) Micro-power generation

(10) Increased reliability and robustness of network equipment.

Mathematical Trick: $2^{10}=1024 \sim 1000=30dB$

FUTURE NETWORKS

(4) Multi-layer traffic engineering

- MLTE exploits traffic statistics to re-route traffic away from under-utilised nodes
- If the traffic rate reduces below a pre-defined low-level threshold (LLT) , traffic is groomed onto relatively more popular router nodes
  - IP routers more efficient (c.f. CMOS) when running at higher capacities
- The routers in relatively under-utilised nodes switched into an idle state.
  - 3dB (50%) improvement in energy efficiency is plausible

(5) Powering-down, sleep-mode, burst-mode operation

- Disadvantage of circuit switching is its inefficient use of network resources,
  - E.g. a data pipe is setup but kept in operation with no traffic.
- Statistical signatures of most traffic sources don't lend themselves to efficient aggregation. Fortunately, central limit tendencies allow the data power envelope to be "surfed".
  - Preliminary experiments show that 3.4 dB energy saving can be expected,
  - Interdependence with MLTE limits overall combination of (4) and (5) to 6 dB.

(6) Optical bypass – avoid OEO, OE or EO conversions

- Current IP routers still require full OEO conversion
  - Future predictions project them to consume 90% of overall network power.
- If at least half the number of nodes can be optically bypassed by a packet traversing the network, this represents at least a 50% saving in IP router energy
  - a further 3 dB reduction in energy consumption.

(10) Increased reliability & robustness – avoid dualling

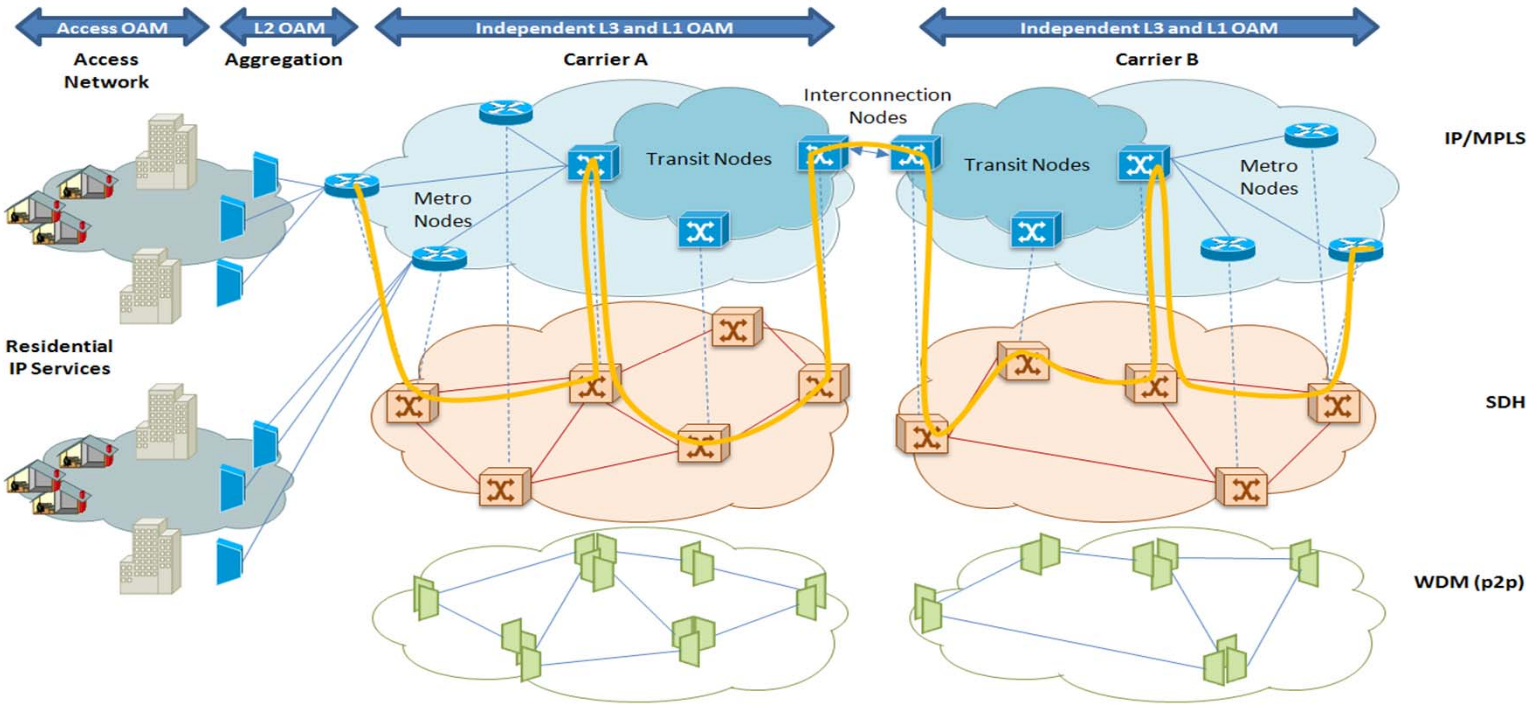
- A large (50%) degree of redundancy is frequently required in network architectures to satisfy the demands for a certain level of quality of QoS.
- 50% saving in overall network energy consumption/CO_2-footprint is possible
  - Avoid network dualling
  - reduced no. of truck-rolls
  - Enhanced network intelligence: Zero-touch & soft-photonics

STRONGEST solutions

- **STRONGEST approach: leverage mostly on architecture (beside technologies)**
- **STRONGEST approach is based on:**
  - **the design of an evolutionary transport network architecture, ensuring higher scalability, cost effectiveness able to** reduce the energy consumption **of the telecommunication network.**
  - **The investigation on efficient combinations of optical and electrical components and equipment**
  - Optimization **of use of network resources**

Transport network architecture

current situation: IP over SDH and/or static DWDM



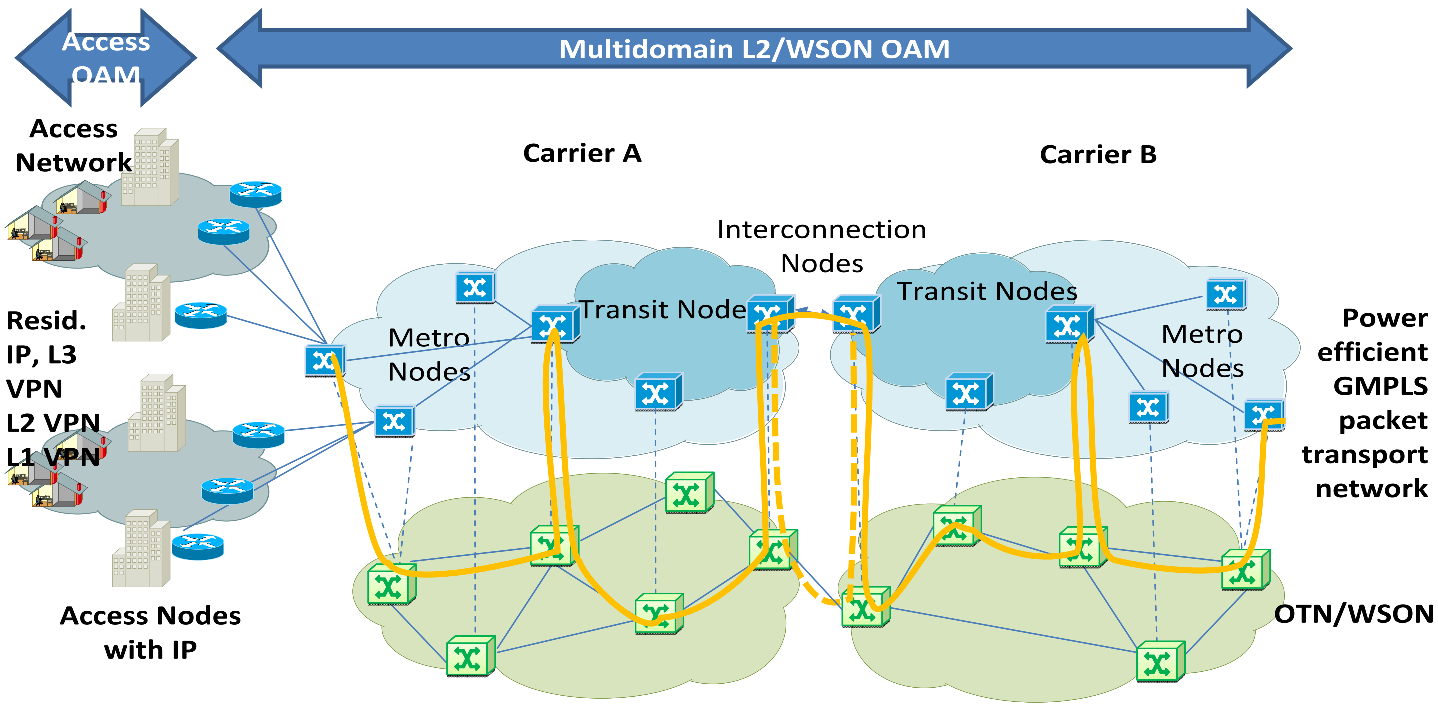
dBε=160

- Completely inefficient architecture, from the power consumption point of mainly view due to massive IP switching.
- With increasing bit rates the power consumption for routers is becoming a bottleneck.
- Routers have exponentially increasing power consumption as a function of the bit-rate.

FUTURE NETWORKS

Mid-term transport network architecture

IP only at the edge



dBε=150

- 10 dB (10 factor reduction)

Traffic is mainly switched at packet transport or optical level instead of IP

•Lower power consumption per bit/s (-60% power consumption)

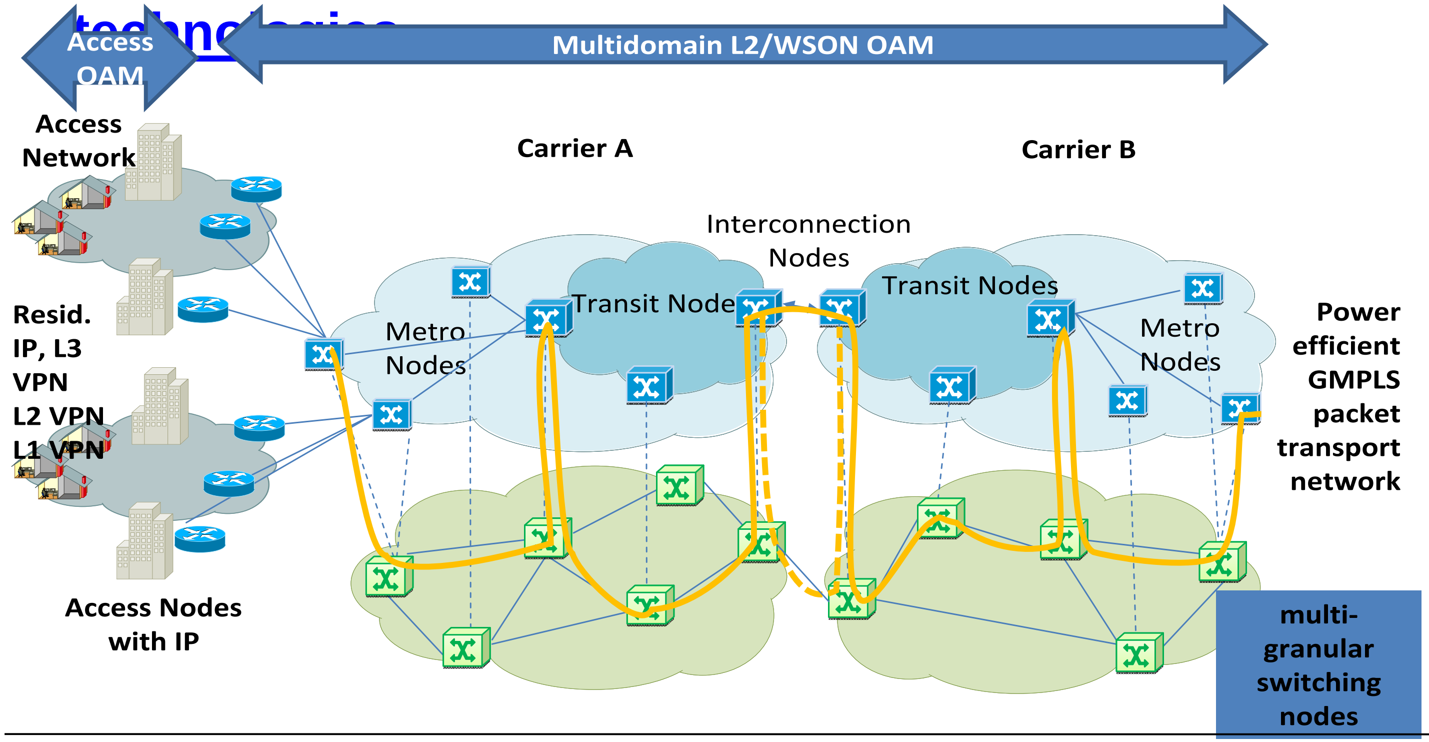
•Carrier class devices avoiding dualling (-40% power consumption)

Control plane enhancement enabling dynamic traffic engineering

- Multi-layer traffic engineering (-30% power consumption)
- Powering down, sleep/idle modes and burst-mode operation (-10% power consumption)
- Dynamic (on-the-fly) restoration (-30% power consumption)

Long term transport network architecture

ultra high capacity and energy-efficient data plane technologies



dBε=138

- 22 dB (140 factor reduction)

Traffic is mainly switched at optical level, enriched by multi-granular / flexi-grid technologies and sub-lambda switching

- Complete optical bypass (-90% power consumption)
- Multi-granular flexigrid (-30% power consumption)