
cnit

ECO net
low Energy COnsumption NETworks

# *Green Networking in Wired and Wireless Networks – Bridging the Gap*

***Franco Davoli***

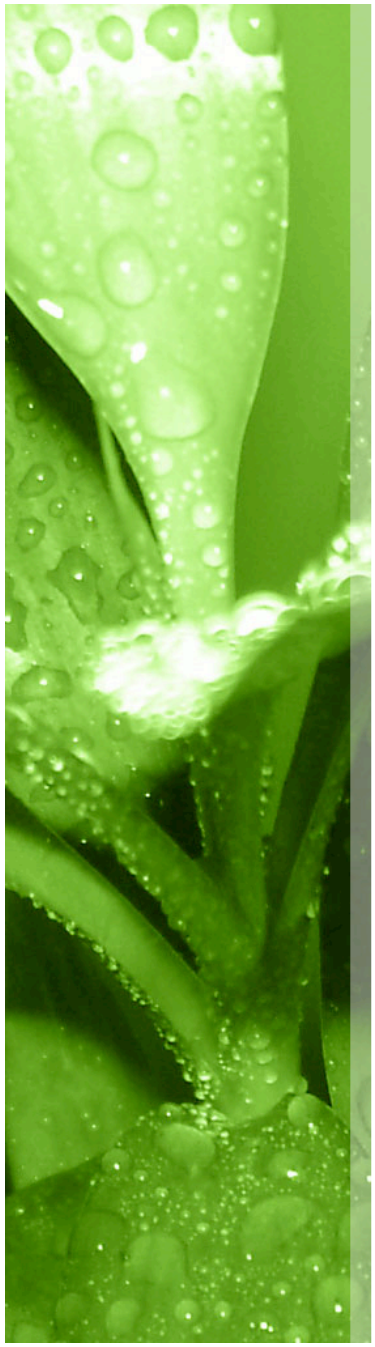
National Inter-University Consortium for Telecommunications (CNIT)

and DIST-University of Genoa
Via Opera Pia 13
16145 Genova, Italy
Visiting Erskine Fellow, University of Canterbury, Christchurch, NZ

franco@dist.unige.it

Christchurch, New Zealand,
Aug. 2011

**2011 IEEE NZ Wireless Workshop**



# *Outline*

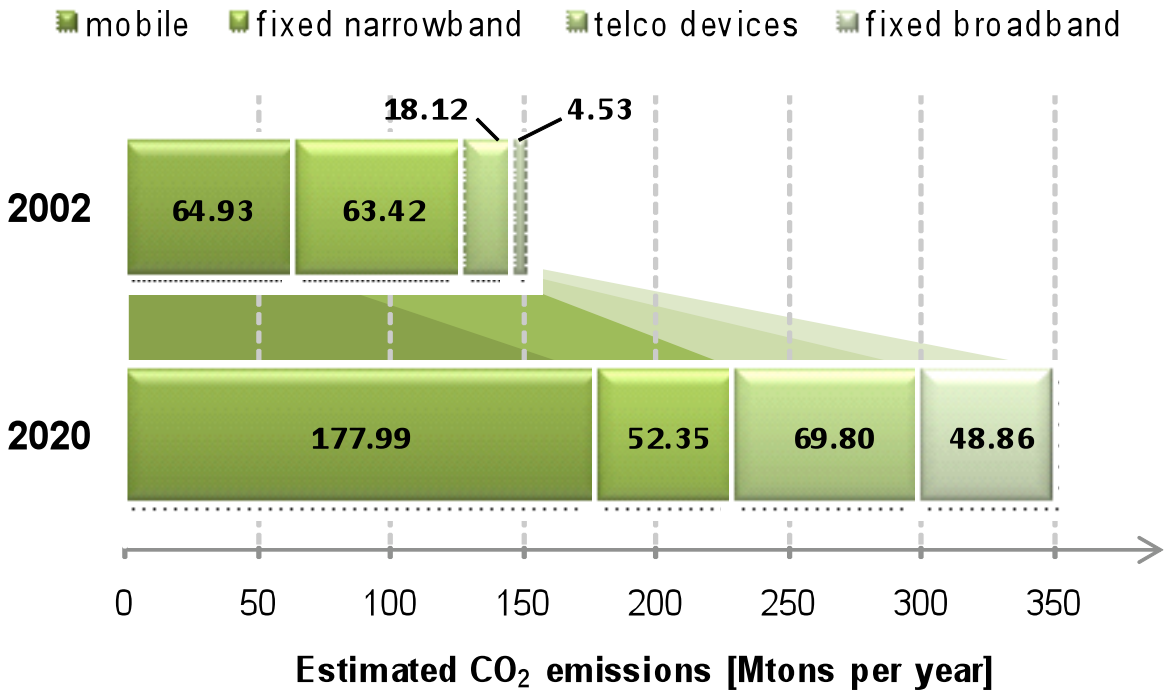
- Relative weights in power consumption
- Energy consumption breakdown
- Taxonomy of Green Networking approaches
- Does the fixed network matter (potential saving)?
- Wireless potentials
- Wireless-wired contact points

# Power consumption in networking – Some data from Telcos

| Energy Consumption (TWh per year) | | | | | |
|---|---|---|---|---|---|
| **Telecom** | **2006** | **2007** | **2008** | **2009** | **2010** |
| **Deutsche Telekom (World)** | 7.10 | 7.22 | 7.84 | 7.91 | - |
| **France Telecom (World)** | 3.66 | 3.47 | 4.57 | 4.38 | - |
| **Telecom Italia** | 2.10 | 2.15 | 2.13 | 2.14 | - |
| **British Telecom (UK)** | 1.94 | 1.99 | 2.03 | 2.28 | 2.28 |
| **British Telecom (World)** | - | - | 2.6 | 2.71 | 3.12 |
| **AT&T (World)** | - | - | - | 11.07 | 11.14 |
| **Verizon** | 8.90 | - | - | 10.27 | 10.24 |
| **NTT** | - | 2.76 | 2.76 | 2.75 | - |
| **Telefonica** | 1.42 | - | 4.76 | 5.05 | 6.37 |
| **SwissCom** | - | - | 0.43 | 0.40 | 0.40 |
| **China Mobile** | - | - | 9.35 | 10.62 | 11.94 |
| **SK Telecom** | - | - | 0.94 | 1.09 | 1.09 |

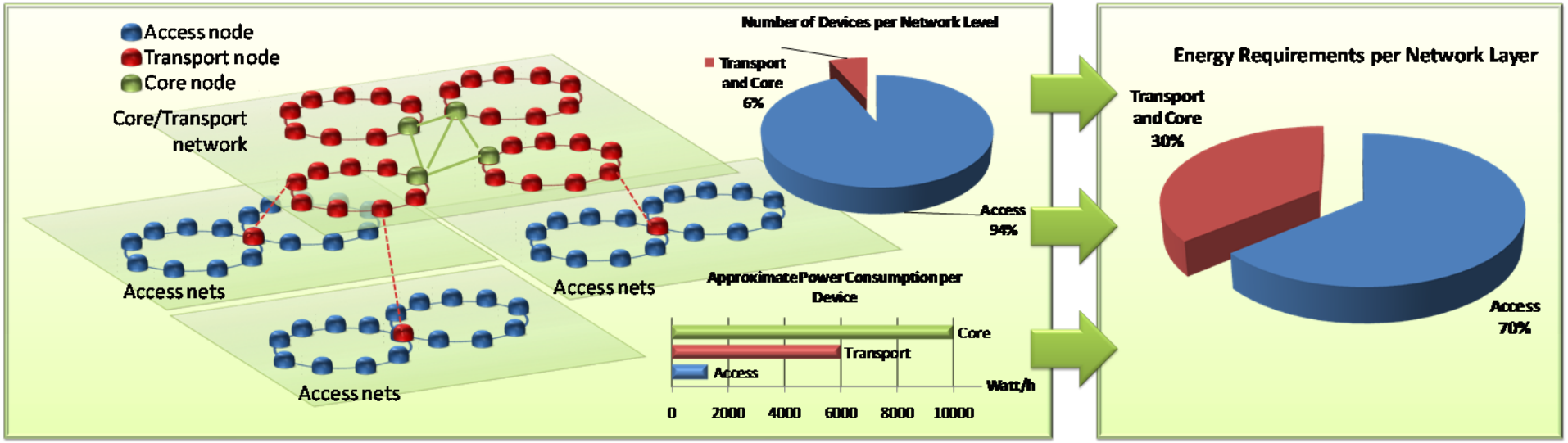
The figures refer to the whole corporate consumption. As such, they account for numerous sources, other than the operational absorption of the networking equipment (e.g., offices' heating and lights). Notwithstanding, they give an idea of the general trend.

# Breakdown by sources




*Source: Smart 2020 report by Global e-Sustainability Initiative (GeSI)*

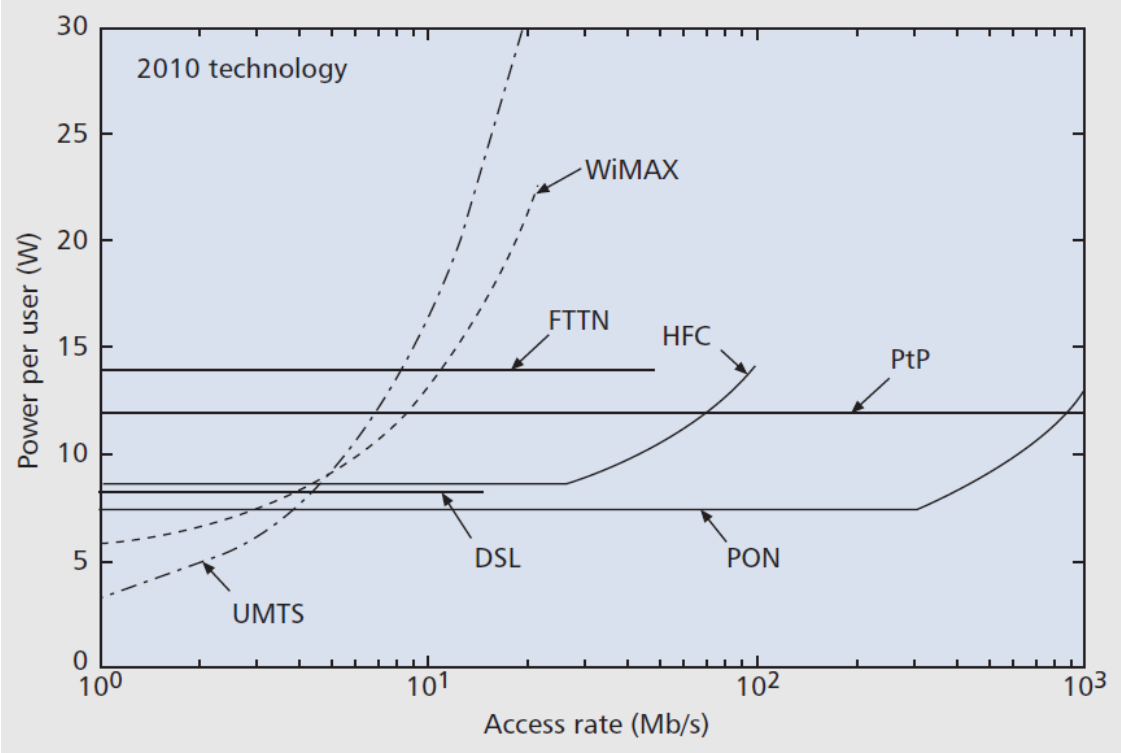
# Decomposing the energy consumption in the wired network




Typical access, metro and core device density and energy requirements in today's typical networks deployed by telcos, and ensuing overall energy requirements of access and metro/ core networks.

*Source:* R. Bolla, R. Bruschi, F. Davoli, F. Cucchietti, "Energy Efficiency in the Future Internet: A Survey of Existing Approaches and Trends in Energy-Aware Fixed Network Infrastructures," *IEEE Communications Surveys & Tutorials,* vol. 13, no. 2, pp. 223-244, 2nd Qr. 2011.

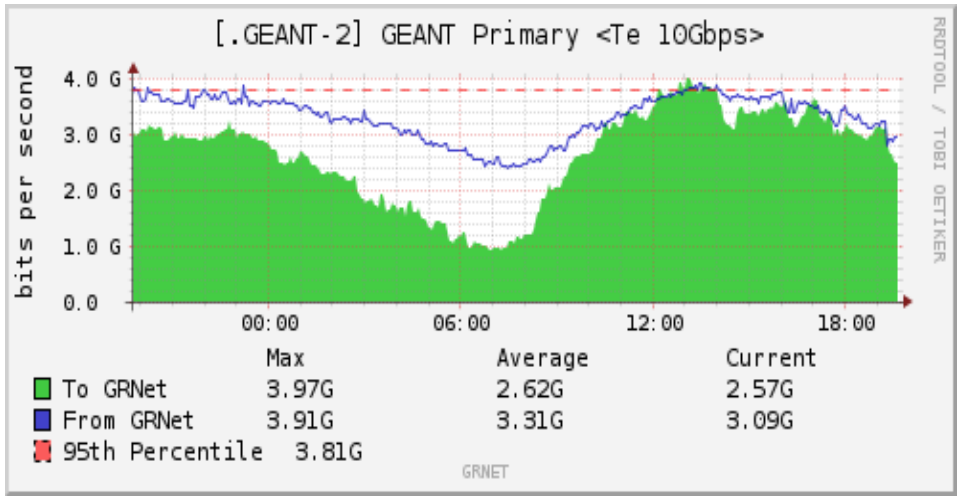
# Access Technologies

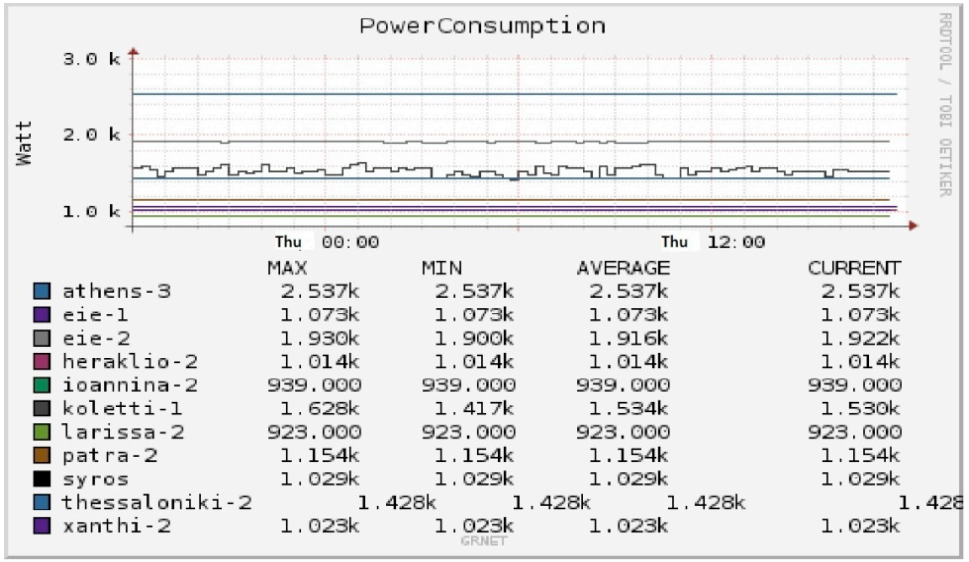



*Power consumption of DSL, HFC, PON, FTTN, PtP, WiMAX, and UMTS as a function of access rate with an oversubscription rate of 20. The technology used is fixed at 2010 vintage for all access rates.*

*Source:* Baliga, J.; Ayre, R.; Hinton, K.; Tucker, R.S.; , "Energy consumption in wired and wireless access networks," *IEEE Communications Magazine,* vol. 49, no. 6, pp. 70-77, June 2011.

# *Is the energy consumption currently load-dependent?*



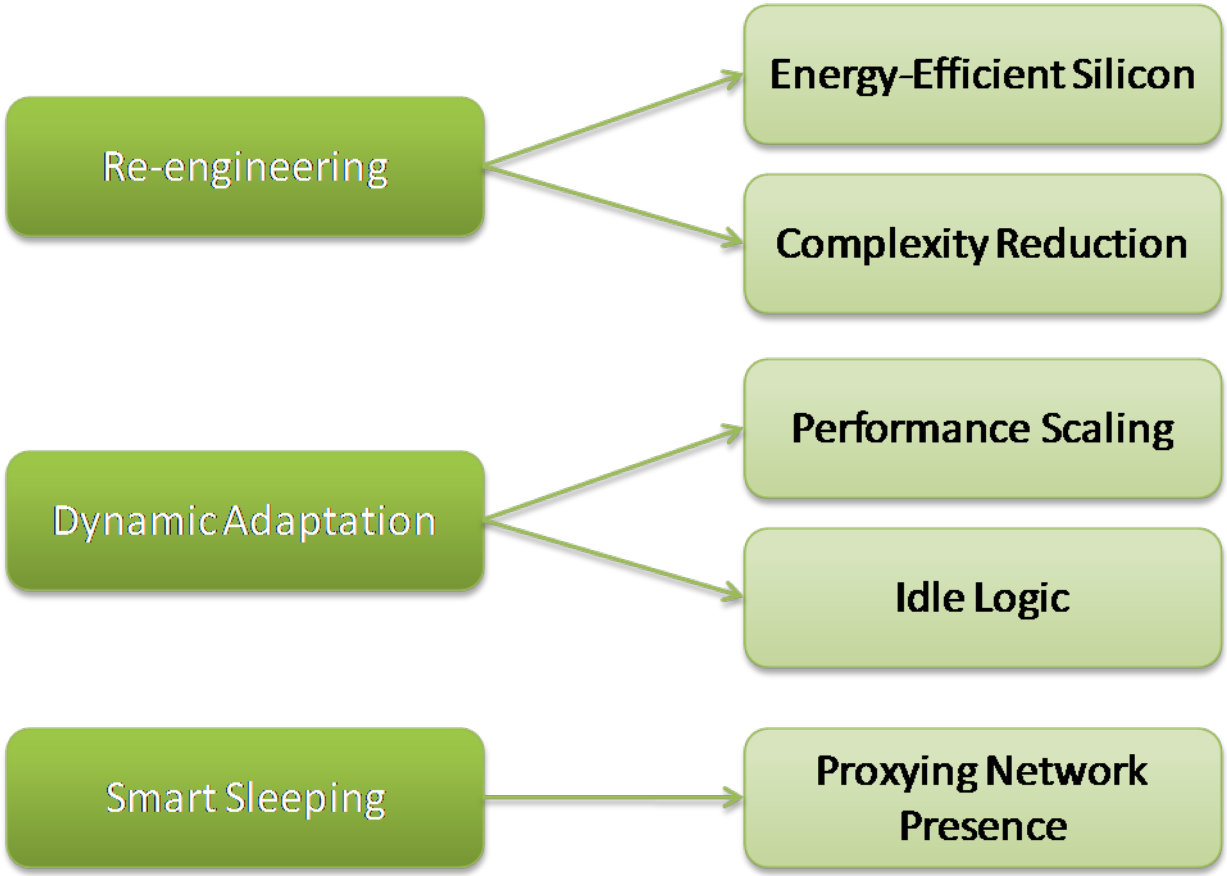




Network engineers only speak about the capacity of a device or of a link interface…

…as a matter of fact, device and link are specifically designed to work at the maximum speed…

*Source*: The ECONET Consortium, ”End-user requirements, technology specifications and benchmarking methodologies,” Deliverable 2.1.

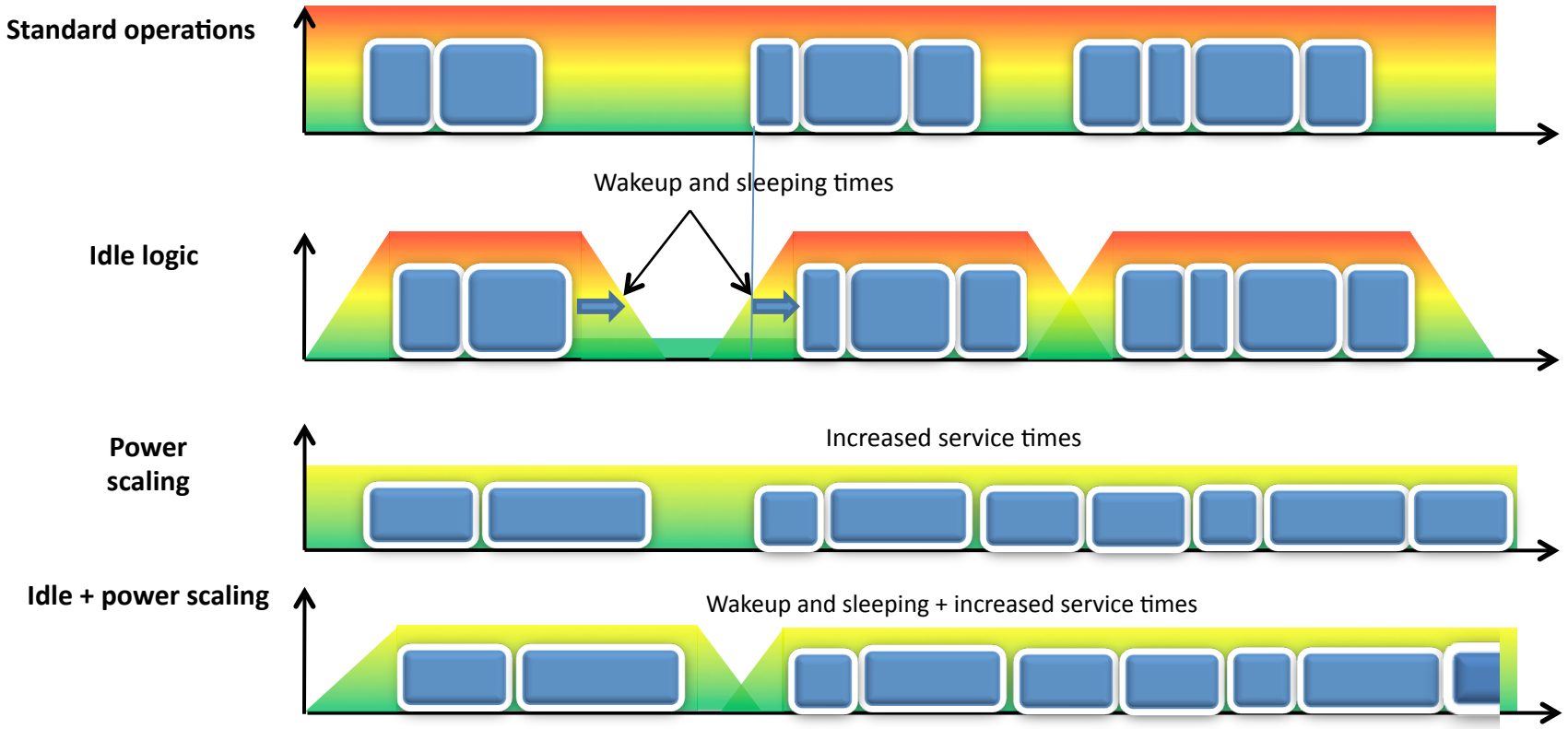
# A Taxonomy of Green Networking Techniques




Techniques can be applied at device, link, and network levels. Most of them apply to both wired and wireless.

*Source*: R. Bolla, R. Bruschi, F. Davoli, F. Cucchietti, "Energy Efficiency in the Future Internet: A Survey of Existing Approaches and Trends in Energy-Aware Fixed Network Infrastructures," *IEEE Communications Surveys & Tutorials,* vol. 13, no. 2, pp. 223-244, 2nd Qr. 2011.

# Dynamic Adaptation

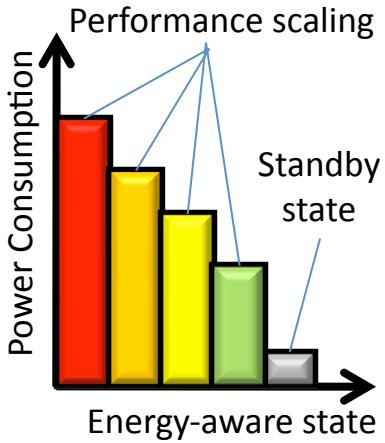


# *Sleeping/standby*

- Sleeping/standby approaches are used to smartly and selectively drive unused network/device portions to low standby modes, and to wake them up only if necessary.
- However,
  - since today's networks and related services and applications are designed to be continuously and always available,
  - standby modes have to be explicitly supported with special techniques able to maintain the "network presence" of sleeping nodes/components.

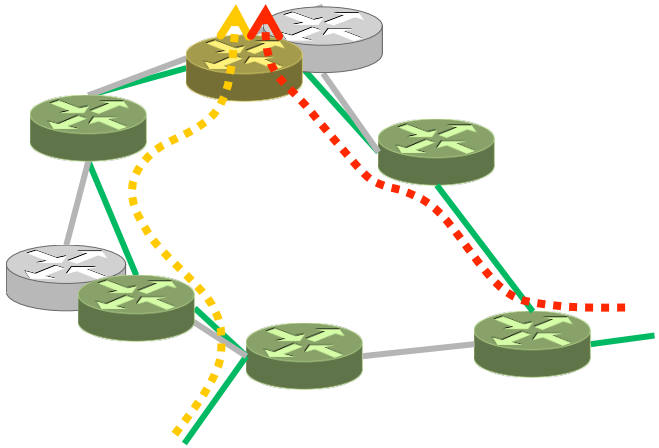
# *Green network-wide control: traffic engineering and routing*

- **Standby states have usually much lower energy requirements than active states.**
- Network-wide control strategies (i.e., routing and traffic engineering) give the possibility of moving traffic load among network nodes.
- **When a network is under-utilized, we can move network load on few "active" nodes, and put all the other ones in standby**.
  - Different network nodes can have heterogeneous energy capabilities and profiles.
- Recent studies, obtained with real data from Telcos (topologies and traffic volumes) suggested that network-wide control strategies could cut the overall energy consumption by more than 23%.

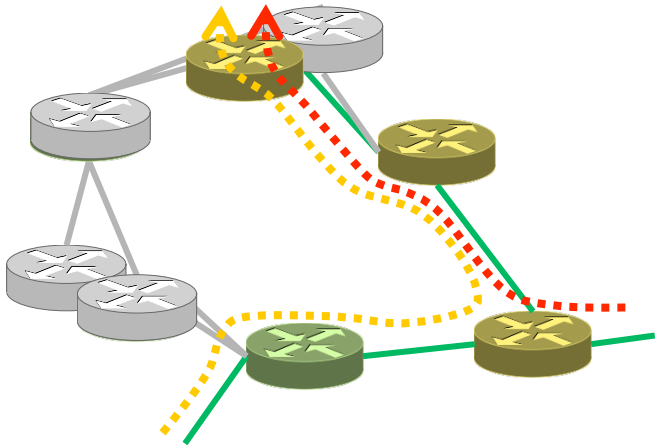


# *Green network-wide control: traffic engineering and routing*

**Only local control policies**



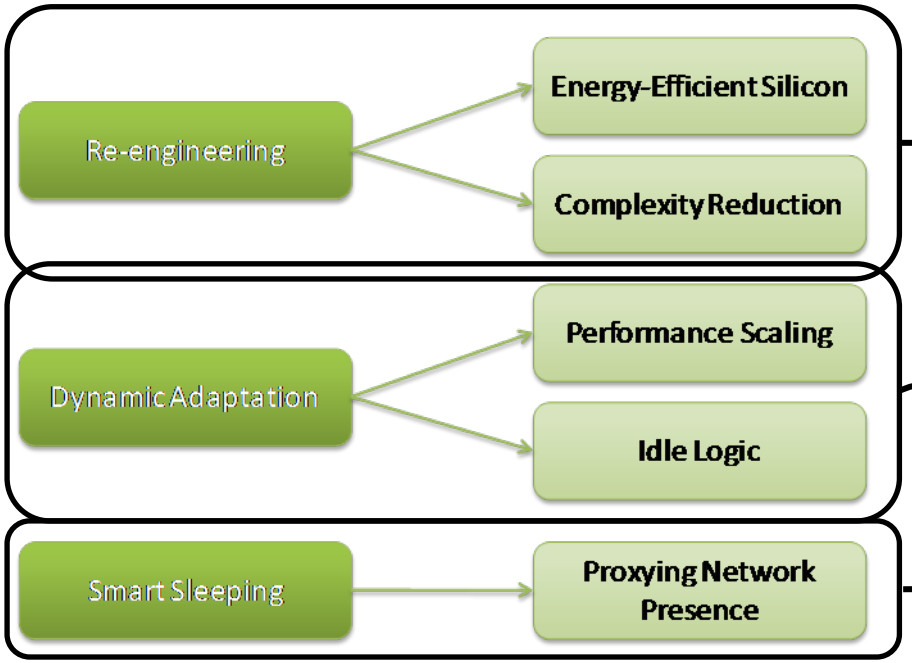
**Local + network-wide control policies**

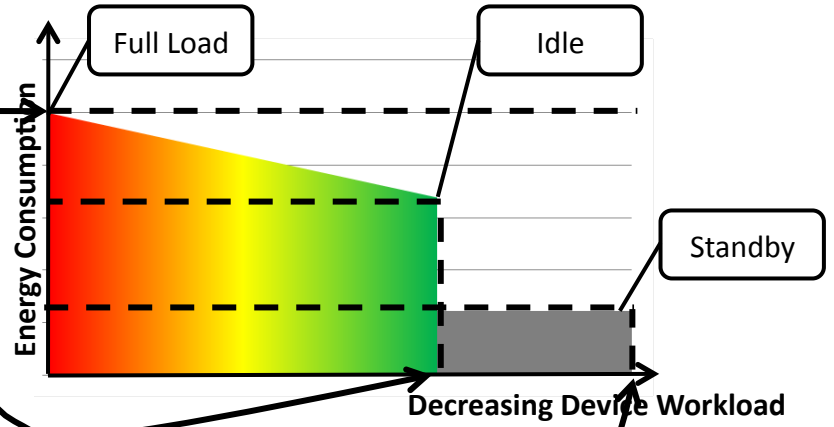


Once network devices will include energy management primitives, further energy reduction will be possible by moving traffic flows among the network nodes, in order to minimize the energy consumption of the entire infrastructure. This is definitely a point of contact between wired and wireless.

# Potential impact on wired

- Green technologies allow designing new-generation network devices, characterized by "energy profiles". Calculations on a typical Telco network of ca. 18 million customers show potential saving is in the order of 70%.



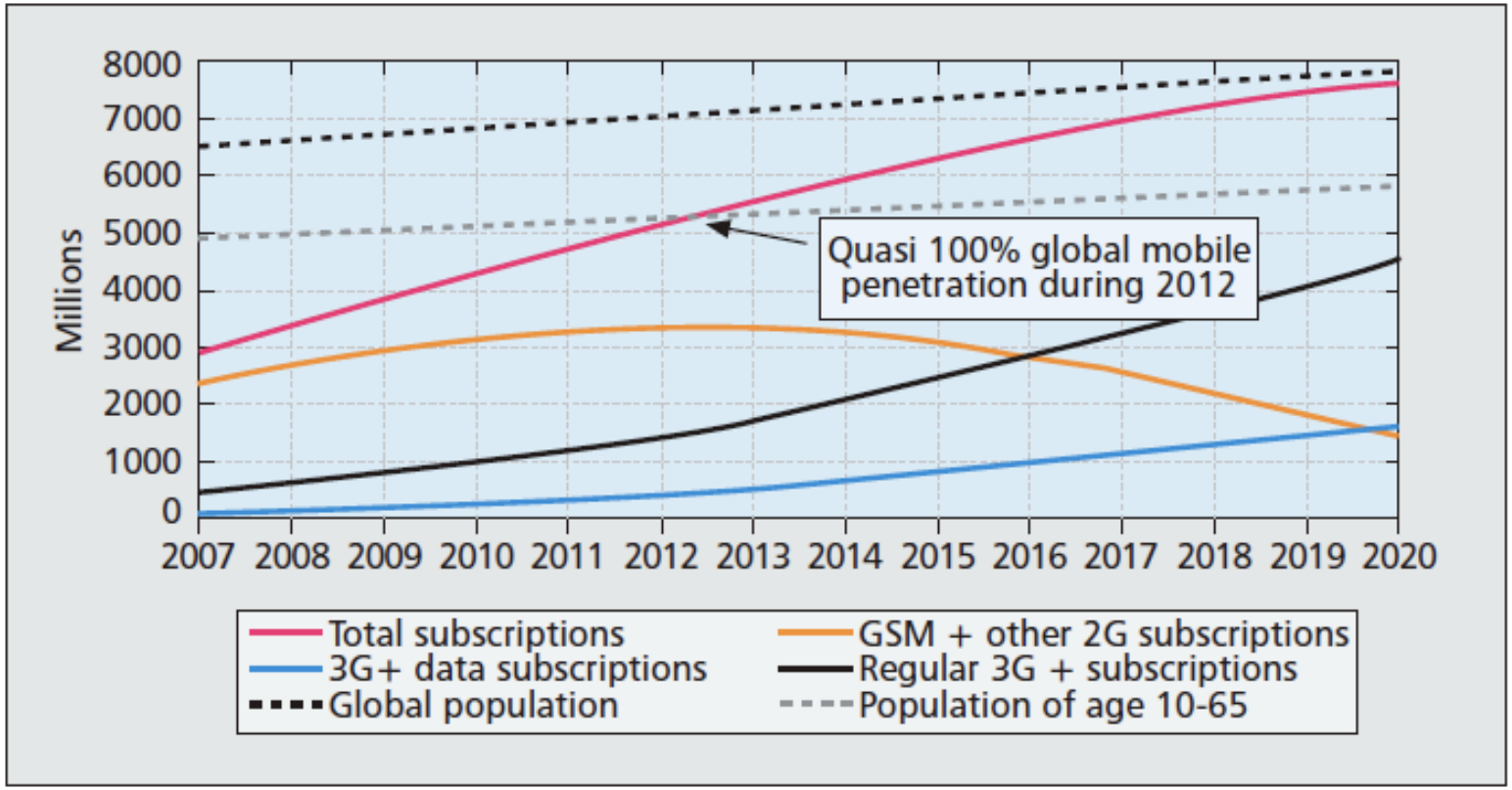




Source: R. Bolla, R. Bruschi, K. Christensen, F. Cucchietti, F. Davoli, and S. Singh, "The Potential Impact of Green Technologies in Next-Generation Wireline Networks – Is There Room for Energy Saving Optimization?," *IEEE Communication Magazine (COMMAG)*, Special Topic in "Green Communications," vol. 49, no. 8, pp. 80-86, Aug. 2011 .

# *A glimpse on Green Wireless Networks*

- Green Wireless Technologies have also been an active area of research and development.
- As regards the wireless access network (at 2010 vintage technology!), UMTS and WiMax would present a steep increase in the power consumption per user in passing from 1 Mbit/s to 10 Mbit/s and above access rates, overcoming all other wired technologies. The increase in the number of mobile users is another factor that contributes to the impact of the wireless sector in the energy concern.

# A glimpse on Green Wireless Networks




"Regular 3G+ subscription" refers to subscriptions for regular phones and smartphones. "3G+ data subscription" refers to subscriptions for mobile broadband modules used only in laptops.

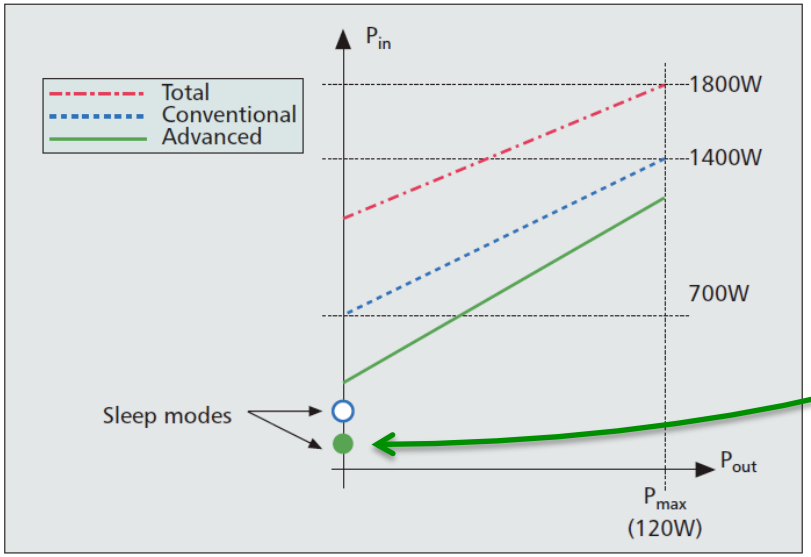
*Source*: A. Fehske, G. Fettweis, J. Malmodin, G. Biczók, "The Global Footprint of Mobile Communications: The Ecological and Economic Perspective," *IEEE Communications Magazine*, vol. 49, no. 8, pp. 55-62, Aug. 2011.

# *A glimpse on Green Wireless Networks*

- Unlike mobile phones, where the embedded carbon is the main contribution to the carbon footprint, "on the network side the big saving potential lies in the operation." [L. M. Correia *et al.*, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks," *IEEE Commun. Mag.*, vol. 48, no. 11, pp. 66-72, Nov. 2010]
- Therefore, great attention has been given to power consumption of the base stations in the mobile environment, spanning a wide range of techniques at the component, wireless link, and network level. Here again, re-engineering (components and deployment), dynamic adaptation, and sleeping techniques find relevant applications. Moreover, the interaction with the backhaul network should be considered in a global optimization.

# A glimpse on Green Wireless Networks

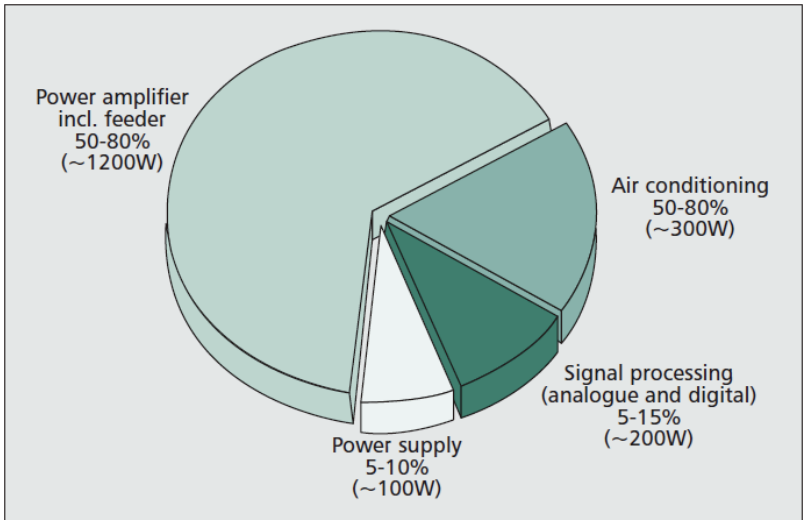
Even a simple linear model relating the input power needed to achieve a certain output at the antenna of a base station and the breakdown of power consumption among the various components can highlight the potentiality for energy saving.




Linear model for a 3-sector macro base station. "Conventional" does not include power supply and cooling.

"Sleep modes" are the basis for DTX (Discontinuous Transmission)

Power consumption breakdown




*Source*: L. M. Correia *et al.*, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks," *IEEE Commun. Mag.*, vol. 48, no. 11, pp. 66-72, Nov. 2010.

# *Potentials for energy gains*

- Main potential reductions in power consumption in base stations can be achieved at:
  - Component Level
    - ✓ Improving power amplifier efficiency
    - ✓ Base station power management (including dynamic adaptation to workload variations)
    - ✓ Deactivation of components (smart sleeping)
  - Link Level
    - ✓ Reference symbol (pilot) & control signal overhead reduction at low load
    - ✓ Baseband signal processing (less advanced Tx techniques in pico/micro cells)
    - ✓ DTX and sleep modes

*Source*: L. M. Correia *et al.*, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks," *IEEE Commun. Mag.*, vol. 48, no. 11, pp. 66-72, Nov. 2010.

# *Potentials for energy gains from interworking with the wired network*

- Network Level
  - ✓ Heterogeneous (macro-, micro-, pico- and femto-cells + relays for coverage extension) network deployment
  - ✓ Network management for coordinated adaptation to traffic profiles
  - ✓ Backhaul network status awareness for information exchange in Coordinated Multi-Point (CoMP) operations

*Sources*:
L. M. Correia *et al.*, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks," *IEEE Commun. Mag.*, vol. 48, no. 11, pp. 66-72, Nov. 2010.
L. Scalia *et al.*, "Power-Efficient Mobile Backhaul Design for CoMP Support in Future Wireless Access Systems," *Proc. IEEE INFOCOM 2011 Workshop on Green Communications and Networking*, Shanghai, China, April 2011, pp. 253-258.