Green Touch™ Initiative:
A Five Year Quest to Achieve Sustainable Networking

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Chairman, Core Switching and Routing Working Group, GreenTouch

September 27th, 2010
Where We Are

- Global Users
- Greater demand for high-speed data
- More applications and services
- Video everywhere
- Sensor deployments and usage (smart grids, security, transportation)

![Carbon Emissions Graph](chart.png)

- Status quo
- Best Case Conventional Networks

300 MtCO$_2$e

2009 2020
Where We Are

- Global Users
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- More applications and services
- Video everywhere
- Sensor deployments and usage (smart grids, security, transportation)

In 2020: > 50 Million Automobiles

Carbon Emissions

- Status quo
- Best Case Conventional Networks

300 MtCO$_2$e

2009

2020
GreenTouch Vision

- Create a radically different network designed for energy efficiency as well as capacity and reliability

- Invent the requisite technologies within the next five years to dramatically increase network energy efficiency for the long term

- Eliminate the need to sacrifice energy efficiency for performance
GreenTouch Mission

- Achieve a 1000-fold improvement in energy efficiency by driving a redesign of communications networks

- Realize efficiency improvements significant enough to offset future carbon emissions from ICT by more than 250 million tons a year

- Accelerate efforts to reduce energy consumption and mitigate the impact of growing consumption
The World Is Going Green

- Smart Grids
- Smart Transportation
- Enabling a Low Carbon Economy
- Smart Buildings
- Smart Communities
- E-Health

**World carbon emissions**

<table>
<thead>
<tr>
<th>Country</th>
<th>Network</th>
<th>Energy Consumption</th>
<th>% of Country Total Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Verizon 2006(1)</td>
<td>8.9 TWh</td>
<td>0.24%</td>
</tr>
<tr>
<td>Japan</td>
<td>NTT 2001(2)</td>
<td>6.6 TWh</td>
<td>0.7%</td>
</tr>
<tr>
<td>Italy</td>
<td>Telecom Italia 2005(3)</td>
<td>2 TWh</td>
<td>1%</td>
</tr>
<tr>
<td>France</td>
<td>France Telecom-Orange 2006(4)</td>
<td>2 TWh</td>
<td>0.4%</td>
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<tr>
<td>Spain</td>
<td>Telefonica 2006(5)</td>
<td>1.42 TWh</td>
<td>0.6%</td>
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</table>

S.Roy, IEEE Intelec 2008
2020 ICT Carbon Footprint

- 2007 Worldwide ICT carbon footprint: 2% = 830 m tons CO₂
- Comparable to the global aviation industry
- Expected to grow to 4% by 2020

820m tons CO₂

360m tons CO₂

260m tons CO₂

Total emissions: 1.43bn tonnes CO₂ equivalent
Current Networks and Trends
Continued Exponential Traffic Growth

Bell Labs Traffic Projections (North America)

- Doubling every 2 years
  - 40% per year
  - 30x in 10 years
  - 1000x in 20 years

- Mix of services is important from energy perspective:
  - Mobile less efficient than fiber optics

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
## Past And Anticipated Internet Growth

<table>
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<tbody>
<tr>
<td>ANNUAL GROWTH RATE (%)</td>
<td>250</td>
<td>200</td>
<td>150</td>
<td>100</td>
<td></td>
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</tbody>
</table>

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

**Internet Traffic Growth Rate**

- RHK - NA
- McKinsey - NA
- MINTS - Global
- Arbor - Global

24-53%/year
Slowdown In Technology

- We are seeing the slowdown in some technologies that we have relied on.
- The reduction in dynamic dissipation of silicon with reduction in feature size is slowing.
- Capacity of single rack IP routers due to thermal density is saturating.
- Capacity of a single fiber transmission system saturating.

Turning points were between 2002 and 2005. Just in the depth of the Telecom winter.
Prediction: ICT Will Save More Energy Than It Will Consume

The Climate Group & GeSI report “Smart 2020”, 2008

Fig. 1 ICT impact: The global footprint and the enabling effect

<table>
<thead>
<tr>
<th>Year</th>
<th>Emissions (GtCO₂-e)</th>
<th>ICT footprint (GtCO₂-e)</th>
<th>Selected ICT-enabled abatements</th>
<th>Other abatements</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>40.0</td>
<td>0.5</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>2020 BAU</td>
<td>51.9</td>
<td>1.4</td>
<td>0.0</td>
<td></td>
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<tr>
<td>2020 with abatements</td>
<td>34.1*</td>
<td>7.8</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>2020 with abatements</td>
<td>201</td>
<td></td>
<td>0.0</td>
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</table>


Figure 1: ICT solutions for the first billion ton of GHG emission reductions and to achieve systemic change
Energy Trending: What We Found ...

- Despite increasing efficiency of network, energy/user or total network energy is rising

Questions
- Can we change this trend?
- What is the best we can do?

2010: 0.007 Mbps/W
What Is Possible? How Far Can We Go?

Bennet and Landauer
Quantum Uncertainty
Thermal Noise
Optical
Keyes
Wireless

“communications networks could be 10,000 times more energy-efficient than they are today”
Network Energy Consumption Lower Bound

Framed question:
What is minimum energy required to uniquely connect N users over long haul distances?

Network Properties
• Connect every pair of users with “Shannon-capacity” fiber
• Use least amount of switching at CMOS estimated-limit
• Energy consumption only depends on size of transaction, not on installed capacity

• Computed lower bounds on energy consumption
• Compares well with bounds computed using thermodynamic framework
• Although practically infeasible, above network guiding the architecture of our ultra energy-efficient networks
Breaking It Down: Baseline Business-As-Usual Trends

- State-of-the-art technology evolution
  - Mix of legacy equipment makes picture worse

- Mobile data is rapidly growing problem today

- Historical energy distribution from edge to core changes over next decade

- Includes 10%/year from Moore’s Law
Best Case (Optimistic) Efficiency Improvements

- **Fixed Access:**
  - Cost-reduced FTTH/N
  - Green PON (from ~16W/user to ~5W/user)

- **Metro/Core:**
  - Mesh protection / fast restoration
  - Dynamic Optical Bypass

- **Mobile Access:**
  - Ultra-efficient power amplifiers (70%)
  - Active antennas
  - Self organizing networks

- **Other:**
  - Passive cooling everywhere
  - Dynamic energy usage (proportional to load)
  - Network Virtualization

![Graph showing power consumption over years from 2010 to 2020](image)

- **Degree of Difficulty:**
  - Lower
  - Higher

Apply uniformly up to 2017
Ideal Efficiency Improvements on BAU: Flat in 2020

Current technology will only sustain us for another decade: how do we go beyond?

Improving network efficiency at best keeps power consumption flat over next decade.

What happens after 2020?

- Can only use ‘sleep modes’ once

![Graph showing power consumption over years from 2008 to 2020. The baseline (BAU) line continues to rise, while the optimistic improvements line plateau in 2020.](image-url)
New Approaches: Focus On Energy

- New devices
  - Analog vs digital, best use of optics and electronics
  - Old ideas finding new life: large scale MIMO
- New architectures
  - Trade-off transmission/bandwidth and processing, distributed versus centralized
- New protocols
  - Longer packet sizes or no packets at all for certain applications
- Service optimized networks
  - Move away from one size fits all—use most energy efficiency hardware for the service
  - Coordinate service delivery/applications with network hardware operation
- Restructuring layers, architectures, feature options
  - How much do we pay in energy for convenience? Duplicated functions (FEC)?
  - What technologies do we really need in order to support the essential capabilities?
Motivation For GreenTouch

- Sustainable Network Growth
  - Energy consumption in ICT networks is increasing as a result of network growth, especially due to the explosion of mobile data traffic
  - Network growth is outpacing equipment efficiency, which is slowing as limits to historical capacity and scaling laws loom
  - This trend could adversely effect the Internet and the broad energy efficiency benefits that ICT networks and associated smart technologies enable

- Energy & Social Responsibility
  - Urgent need to meet the global challenge of reducing greenhouse gas emissions and increasing reliance on renewable sources of energy
  - Every industry must play its part and ICT, at the forefront of technology, can be a leader
  - Real challenges facing ICT Industry: energy costs and government regulations
GreenTouch Consortium

- Draw on expertise across the industry and around the world
- Open invitation to the entire industry
- Committed to open innovation and collaboration to accelerate progress
- Members are experts from world’s top institutions and operators
The Challenge

Demonstrate technologies in 5 years that will lead to a 1,000-fold increase in network energy efficiency

=  

~ 3 Years

Realize savings against future network growth
Why 1000x?

Because...

- Traffic will grow by 1000 within 20 years
- All parts of the network will matter
- All technologies we use in networks will matter
- It makes you question all aspects of the network
- It requires a highly scalable network
- You can’t solve it with growth alone
- You can’t solve it with power reduction alone
- The goal should fit the problem...
Key Obstacles

- End-to-end, holistic approach requires common direction/vision
  - Still need to retain diversity of ideas
- Applying funding where it is needed most
- Magnitude of the effort
- Access to data on equipment and networks
  - Commercial assets
- Creating an environment to support creativity and innovation
  - Among individuals from a wide range of organizations
GreenTouch Approach

- **Bottom Up Research Organization**
  - Purpose is to stimulate and support many diverse research efforts

- **Use models as a framework to guide research and collaboration**
  - Understand how each accomplishment contributes to the larger picture
  - Identify gaps in effort/key challenges
  - Provide the critical resources necessary for research: data, equipment trends, network architectures
  - Gauge impact of innovations on:
    - Alternative metrics (carbon footprint, network power, embedded energy)
    - Adjacent technologies (data centers, handsets)
  - Measure, model and predict energy consumption in ICT networks (equipment trends, traffic, deployment)

- **Facilitate funding rather than ‘fund it all’**
  - Direct member funding targeted to the areas of most interest to for-profit members
  - Work with government agencies to promote research in key areas
  - Provide tools, seed funding, key partners, ...
Metric Is Network Efficiency

Green Services

Increase

Total Traffic Delivered to User
Total Power per User

Growth

Reduce

Reduced Carbon Footprint

Reduced Costs

Increased Revenue from Services

Makes both Environmental and Economic sense
Not Just About Network Efficiency

- Determine impact of GreenTouch innovations on:
  - Alternative metrics: carbon footprint, network power, embedded energy
  - Adjacent technologies: data centers, handsets

- Measure, model, and predict energy consumption in communication networks
  - Equipment trends, traffic, deployment
Consortium 5 Year Goal

Define architectures, demonstrate technologies

How will this work?
Use Architecture Models & Targets To Track Progress

Define architectures and track research results

- Identify targets for each architecture and update network efficiency in model as targets are achieved
  - Working groups define targets and evaluate completion
  - Targets can be achieved within GreenTouch projects or from broader community
  - Identify gaps in effort and solicit new activities
### Simple Spreadsheet Models For Each Architecture

This sheet contains key architecture and scenario defining parameter inputs for model and final results computations.

#### Select Architecture

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<td></td>
<td></td>
<td>1000</td>
<td>Tgi Wi 2020</td>
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#### Efficiency vs. Future Year

- Access
- Transport
- Rig/Bug
- Mobile
- Overall

- Efficiency vs. Power / Energy

#### Architecture 1: Baseline

<table>
<thead>
<tr>
<th>Global</th>
<th>Core/LH</th>
<th>Metro</th>
<th>Access</th>
<th>Enterprise</th>
<th>Wireless</th>
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<tr>
<td>Parameters</td>
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<tr>
<td>Protection (1)</td>
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<td>hops (1)</td>
<td>2 hops (1)</td>
<td>2 hops (1)</td>
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<tr>
<td>Core-Processing (2)</td>
<td>2 hops (3)</td>
<td>hops (3)</td>
<td>2 hops (3)</td>
<td>2 hops (3)</td>
<td>2 hops (3)</td>
</tr>
<tr>
<td>Coding (3)</td>
<td>3 hops LH factor</td>
<td>3 hops LH factor</td>
<td>3 hops LH factor</td>
<td>3 hops LH factor</td>
<td>3 hops LH factor</td>
</tr>
<tr>
<td>Si Alpha (4)</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
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<tr>
<td>N Route (1)</td>
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<td>1</td>
</tr>
<tr>
<td>Units (14)</td>
<td>1 Mio</td>
<td>1 Mio</td>
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</table>

- Access Factor
- Transport Factor
- Rig/Bug Factor
- Mobile Factor
- Overall Factor

### Network Parameters

- Protection (1)
- Core Processing (2)
- Coding (3)
- Si Alpha (4)
- N Route (1)
- Year (2008)
- Units (14)
Modeling Provides Clear Picture Of Goals

Assumptions:
- Baseline year 2010
- Target year 2020
- GreenTouch results in five years: 2015

GreenTouch 5 year Goal: Element efficiency demonstration targets for 2015

Efficiency in Mbps/W

Overall network efficiency target in 2020
Sample Targets Using Baseline Architecture

Overall efficiency improves from $7 \times 10^{-3}$ Mb/s/W to 8 Mb/s/W

- Exceed all mean targets except in fixed access (due to cpe electronics)
- Major innovations required: new protocols/algorithms, ‘beyond Moore’s law’ electronics, hybrid small cell with MIMO, new router/sw architecture, optical restoration & fast switching
GreenTouch Organization

- Executive Board
  - Gee Rittenhouse

Technical Committee
- Dan Kilper, Shugong Xu

Services, Applications Trends
- Steve Korotky

Operations Committee
- Thierry V. Landegem, Kevin Kemp

Network Committee
- Rod Tucker, Man-Fai Wong

Keep structure simple:
- Essential functions: collecting data/inputs; modeling & tracking progress, carrying out research
- Technical Committee provides overall coordination among all technical activities
- Allow for working groups as needed
GreenTouch Working Groups

Working Groups

Access Networks
- Wireline Access Networks
  - L. Lefevre, F. Effenberger
- Mobile Communications
  - A. Pascht, Jongho Bang, E. Calvanese-Strinati

Core Networks
- Core Transmission
  - I. Tomkos, J-C Antona
- Core Switching and Routing
  - T. Klein, A. Pattavina
Coming Back to GreenTouch Goals: Partitioning Energy Consumption in Network
Initial Activities

- First technology demonstration spring 2011
- Establish common reference architecture
- Define primary research targets
- Establish expected trends on key metrics to 2020
- Provide international forum for cooperation and exchange of ideas on energy research topics
Just To Recap ...

- Eco-sustainability is crucial for ICT
- The industry just doesn’t have a current solution
- Recent research confirms that there is a tremendous opportunity
- We’re bringing together the right people from the right institutions from around the world to realize it
a Forum for research ideas

a Vision for future networks

is many things

a Challenge for research

a New Approach in cooperation
Thank You

GreenTouch™

www.greentouch.org