



GREEN RESEARCH AND GREENTOUCH

Innovations for Long-term Sustainable Network Growth

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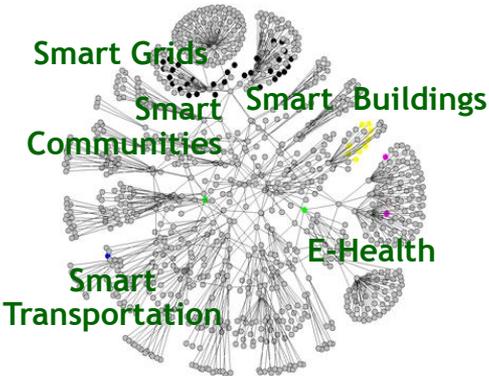
11 October 2011

DRIVERS and GREEN OPPORTUNITY

- **Industry**
 - New value-add Services
 - Mobile broadband everyone, everywhere
 - Increase revenue
 - Reduce Cost
- **Climate change issues**
 - Reduce energy consumption
 - Compliance



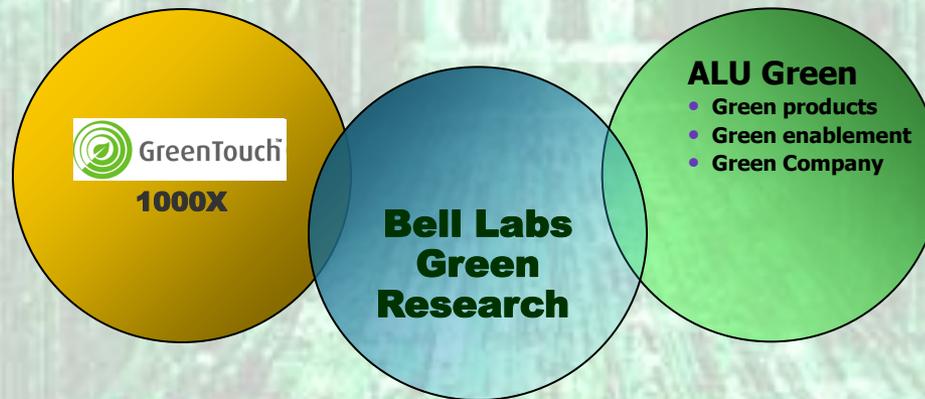
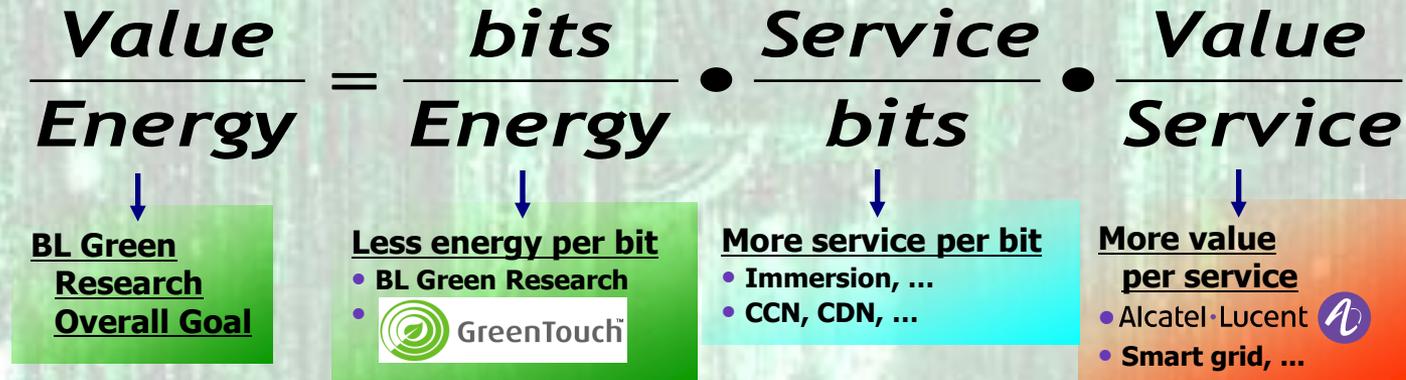
Total emissions: 1.43bn tonnes CO₂ equivalent



Reinvent scalable “green networks”

Green: Providing "Value" at "Minimal Energy"

- "Information" is a critical component of value
- ICT networks: ultra energy-efficient in producing and transporting information
- Green is the product of everything we do in the Company



Green is a great opportunity



By 2015, deliver architectures, specifications, roadmaps, and demonstrate key technologies needed to increase network energy efficiency by a **1000-fold over current levels**

- Global consortium with **experts** from across industry and world's top institutions collaborating in matrix of **open-innovation**, establishing roadmaps, listing challenges and focusing on highest opportunity
- **Pre-competitive** research that emphasizes clean slate architectures and **out-of-the-box** thinking
- **Support and Funding** from members and Governments
- **Ambitious goal** in finite period of time



GreenTouch™ MEMBERS – GROWING LIST

- AT&T
- Athens Information Technology (AIT) Center for Research & Education
- Bell Labs
- Broadcom
- Carnegie Mellon University
- CEA-LETI Applied Research Institute for Microelectronics
- **China Mobile**
- Chunghwa Telecom
- Columbia University
- Draka Communications
- Dublin City University
- Electronics and Telecommunication Research Institute (ETRI)
- Energy Sciences Network/Lawrence Berkeley Labs
- Fondazione Politecnico di Milano
- France Telecom Orange

- Fraunhofer-Gesellschaft
- Freescale Semiconductor
- The French National Institute for Research in Computer Science and Control (INRIA)
- Fujitsu
- Huawei
- IBBT
- IMEC
- Karlsruhe Institute of Technology
- Katholieke Universiteit Leuven (K.U. Leuven)
- King Abdulaziz City for Science and Technology
- KT Corporation
- National ICT Australia
- NTT
- Politecnico di Torino
- Portugal Telecom Inovação, S.A.

- Samsung Advanced Institute of Technology
- Seoul National University
- Swisscom
- TNO
- Tsinghua University
- TTI
- TU Dresden
- Universitat Paderborn
- University College London
- University of Cambridge
- University of Delaware
- University of Leeds
- University of Manchester
- University of Maryland
- University of Melbourne's Institute for a Broadband-Enabled Society (IBES)
- University of New South Wales
- University of Toronto
- Waterford Institute of Technology



GreenTouch™ Focusing on Biggest Wins

GreenTouch™ has established technical working groups to focus on the activities with the highest estimated potential of improving energy efficiency in communications networks

Technical Working Groups

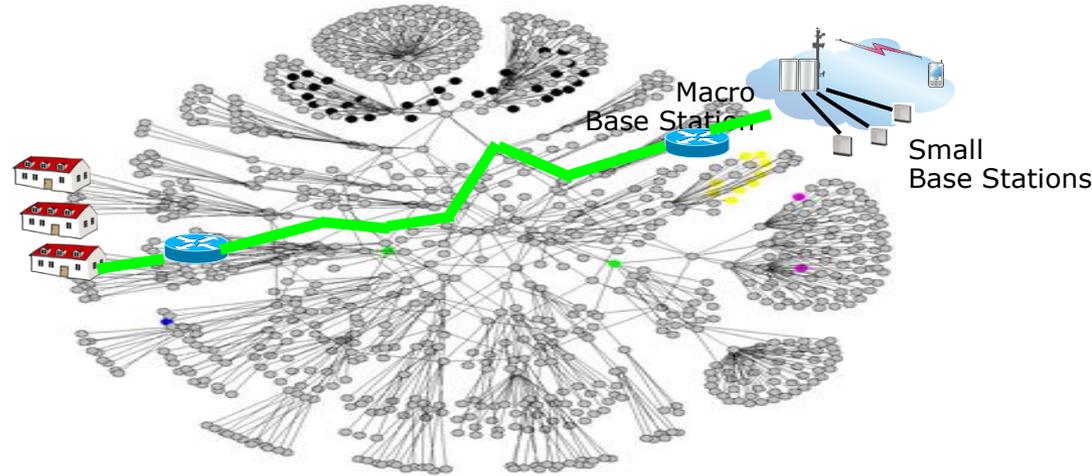
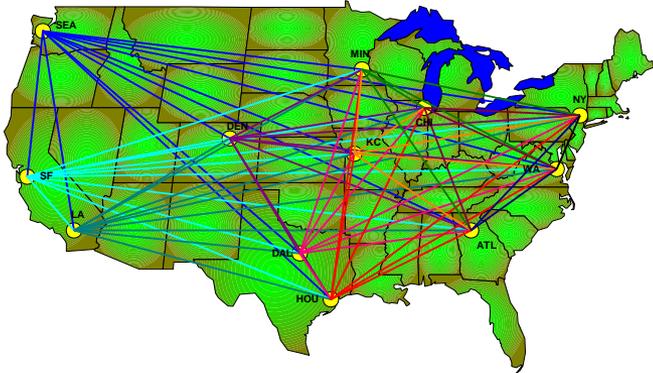
Input to Working Groups comes from Services, Applications & Trends Committee

- Wireless (**1000X**)
- Wireline Access (**100X**)
- Core Routing & Switching (**100X**)
- Core Optical Networking and Transmission (**10X**)

Across the Working Groups there are More than 15 Collaborative Projects Underway

Infrastructure & Ideas in place to maximize success

Energy Efficient Network Architectures



Lower Bound Architecture: Full Mesh

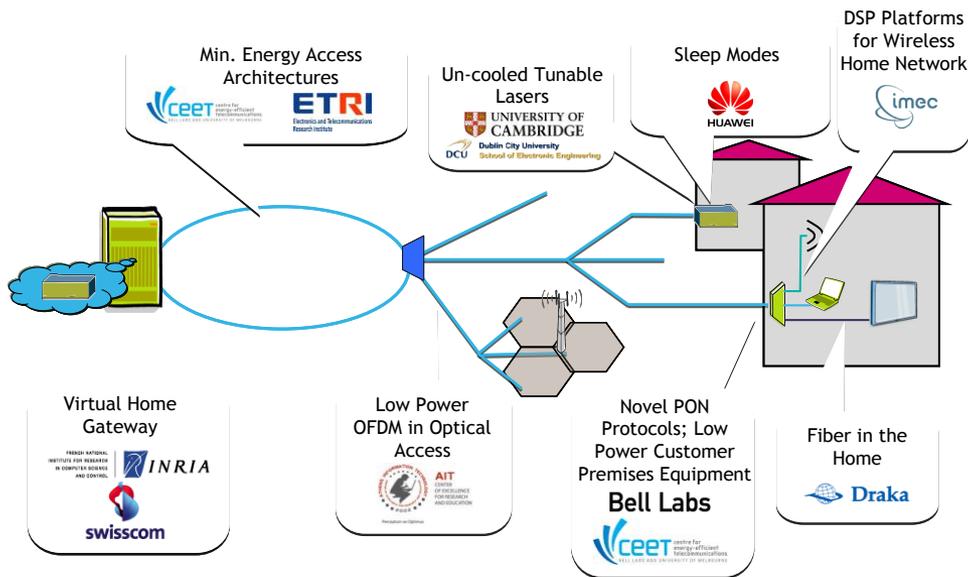
- Connect every pair of users with “Shannon-capacity” fiber
- Use least amount of switching at CMOS estimated-limit
- Energy consumption only depends on size of transaction, not on installed capacity

Practical Green Architectures

- In real networks (mesh in the core, tree at the edges), dynamically allocate/switch a virtual fiber link between the two end-points of a transaction, with minimum routing
- Bring antenna as close to user as economically feasible; design for high antenna gains; opportunistic use of high BW
- Service aware and adaptive network with ultra-low energy information and content delivery
- Low Power, ultra-high energy efficiency, energy-follows load components everywhere

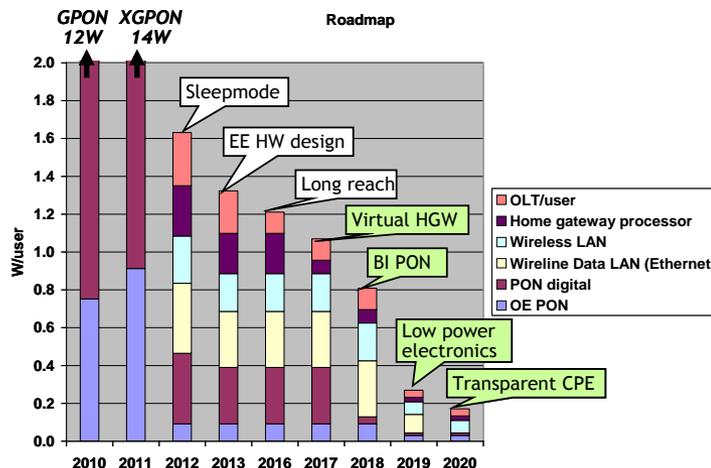
Challenging ourselves to think beyond!

For Fixed Access [Goal: ~100x]



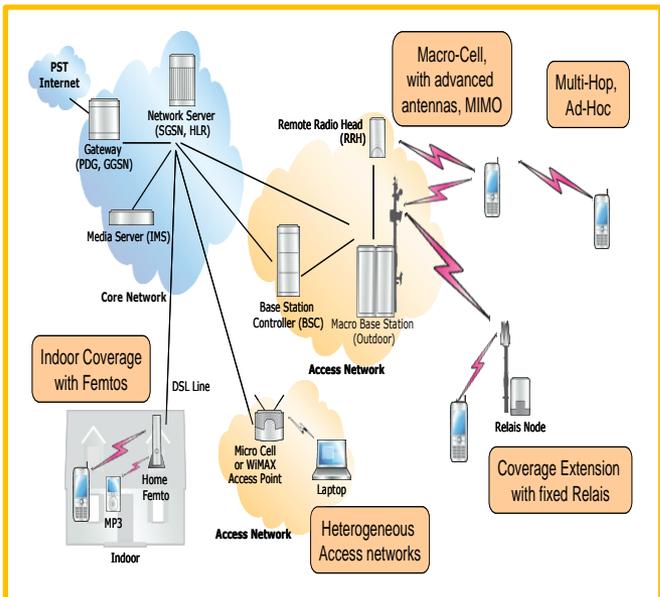
Basic Ideas:

- Make a shared transport medium behave more like a dedicated one per user
- Very high resolution sleep modes and energy efficient protocols
- Dramatic reductions in processing speeds to
 - Reduce computational power at CPE
 - Fault-tolerant computing
- Energy efficient node architecture for NG Access Node (not GT)



- Aggressive roadmap for 100x improvements
- GT-Demo planned for Feb 2012 to show reduction of > 10X in network termination power at CPE

For Green Wireless [Goal: ~1000x]



Analysis Results:

- **Green air interface**
 - Large scale antenna systems
 - Small cells
 - Very high BW
- **Network arch.& management**
 - Hybrid deployment
 - Smart energy management
 - Cloud-computing for signal processing
- **Base station hardware**
 - Ultra Low-Power Base-Station on a Chip
 - Photonic Enablers for RF Systems
 - High Efficiency RF-Power Amplifiers
 - Renewable Energy Powering
 - New Architectures such as lightRadio™

Common issues:

- **Huge increase in antenna (and radios) that have to be power-smart and adaptive**
- **Ultra-low power quiescent states**
- **Computational complexity**
- **Back-haul**



“LightRadio is a smart solution to a tough set of problems: high energy costs, the explosion of video on mobile, and connecting the unconnected.”
Ben Verwaayen, CEO of Alcatel-Lucent

LightRadio-Like Elements and Green Wireless

- **As an energy-efficient, scalable and multi-band radio front-end that permits shared BB processing, LightRadio is well aligned with emerging green wireless architectures**

Large Scale MIMO

Concept

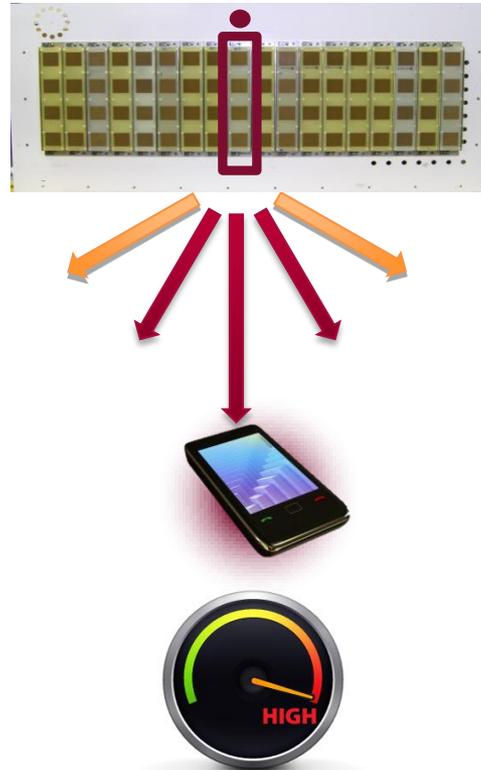
Potentially 100x increase in wireless energy efficiency through selective beam-forming, in highly cluttered environments, using base-stations with hundreds of antenna

Challenges

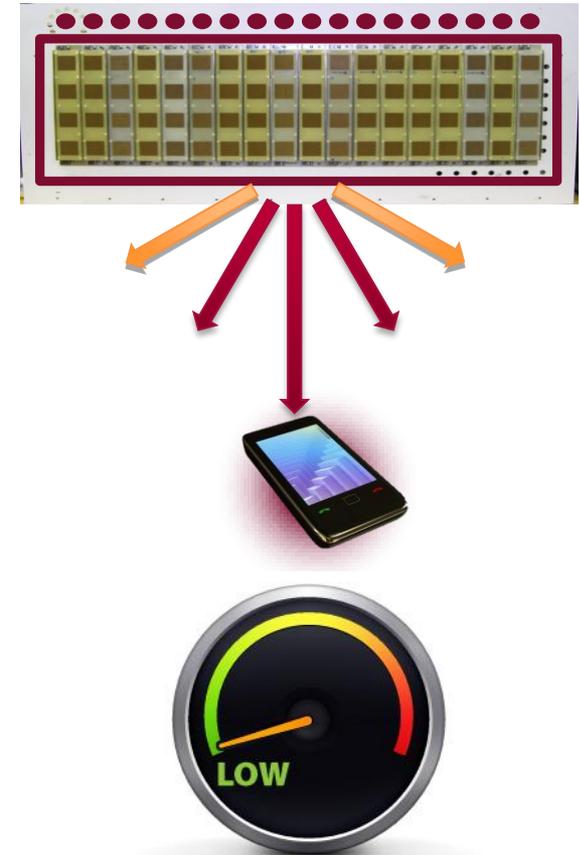
- Base-station design
- Acquiring CSI, calibration, etc.
- Total power reduction
- New standards

Collaborators

- Bell Labs
- Freescale
- Orange
- Huawei
- ...



Power used = 16



Power used = 1

First result demonstrated successfully in London on Feb 1, 2011

Acknowledgement: Passionate & Dedicated Support of Leadership Team



Ingredients for Collaborative Global Innovation

- **Strong value proposition that clearly demonstrates need for global partnership**
- **Top leadership support**
- **Organization that facilitates progress**
- **Ambitious milestones and continuous results**
- **Funding**



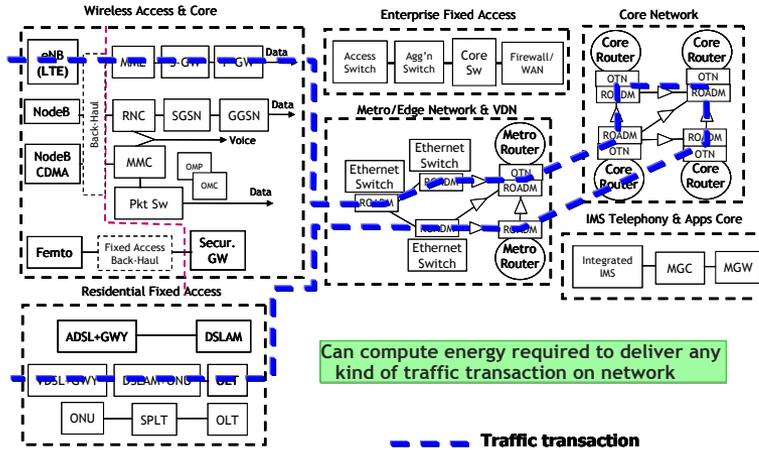
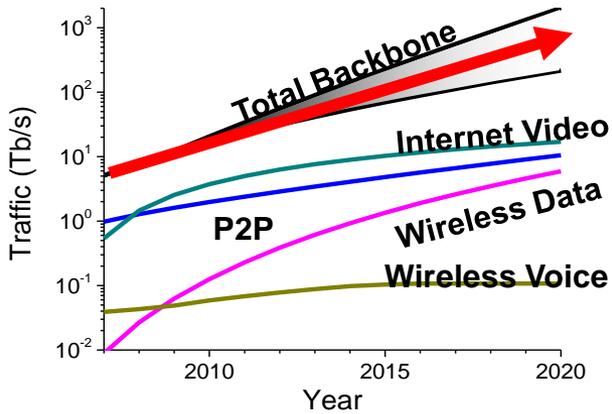
AT
THE
SPEED
OF
IDEAS

BACKUP

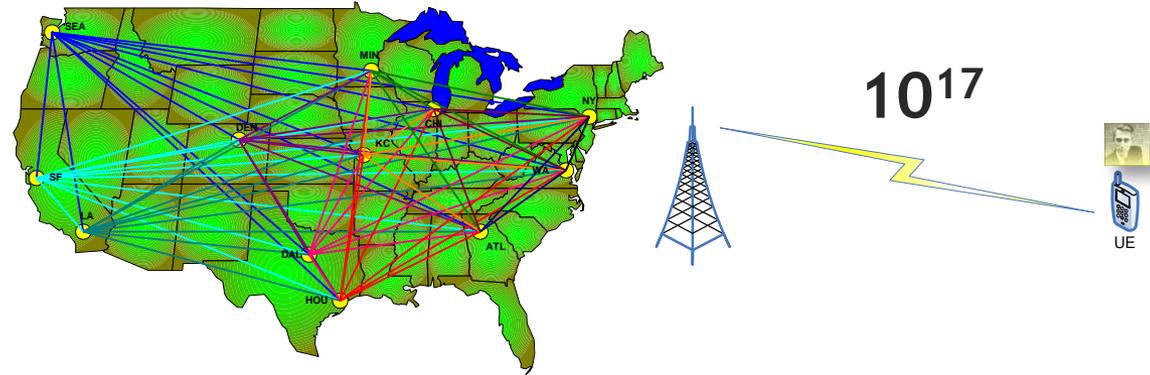
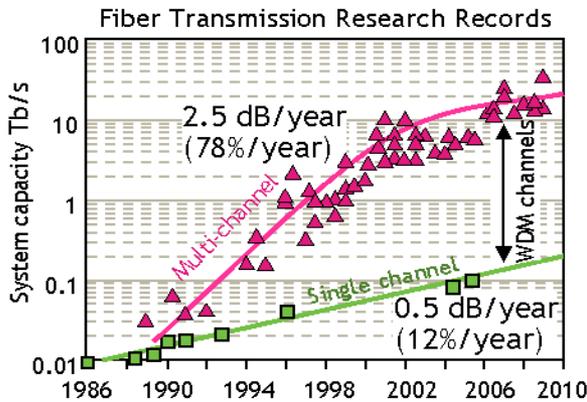
THE CASE FOR GREENTOUCH™

Bell Labs analysis...

Traffic is growing



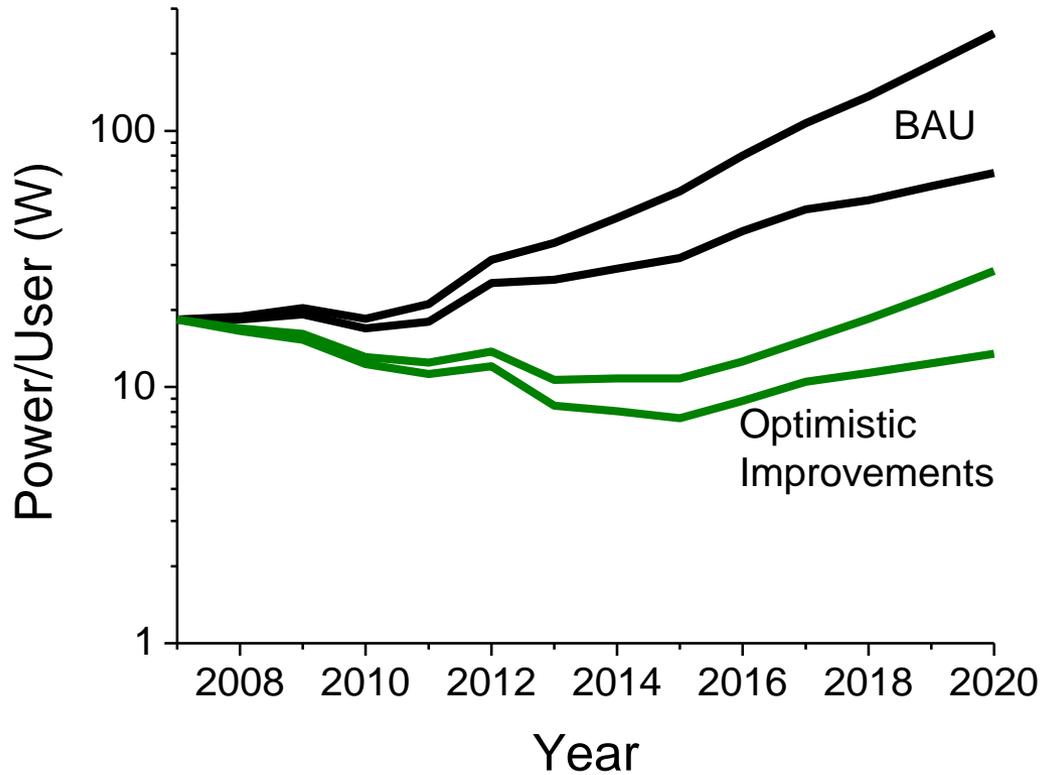
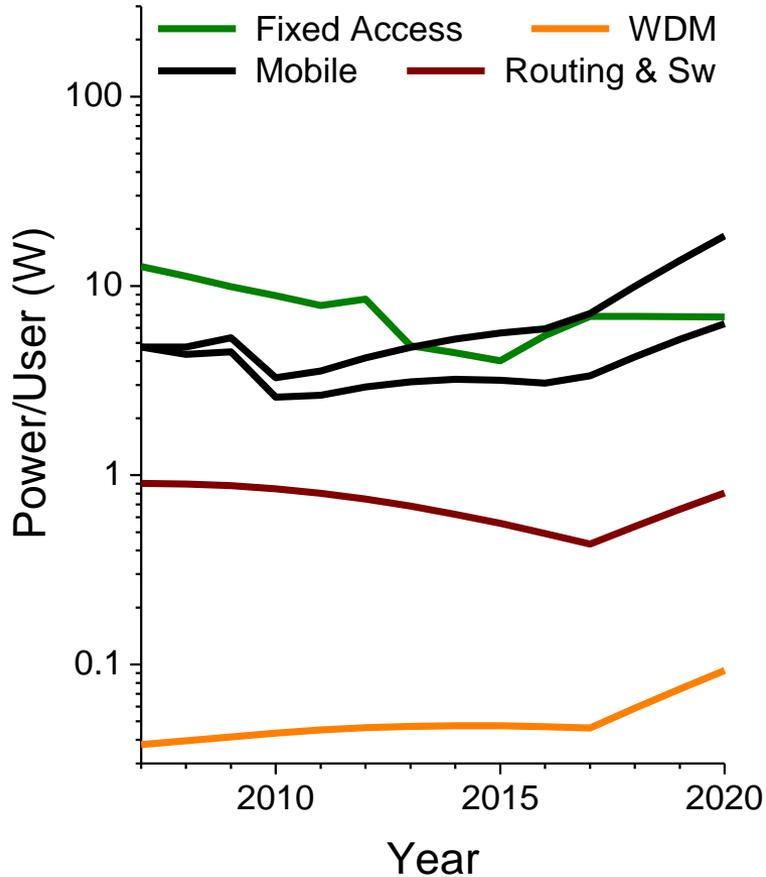
Innovation is slowing



Networks can be 10,000 times more efficient

Trending Shows That Despite Increasing Efficiency, Energy/User in Network is Rising

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





GreenTouch™

GOAL

Environmentally and Economically Sound

Green Services

Increased Revenue from Services

Increase

Growth

Bits per second

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

Watts

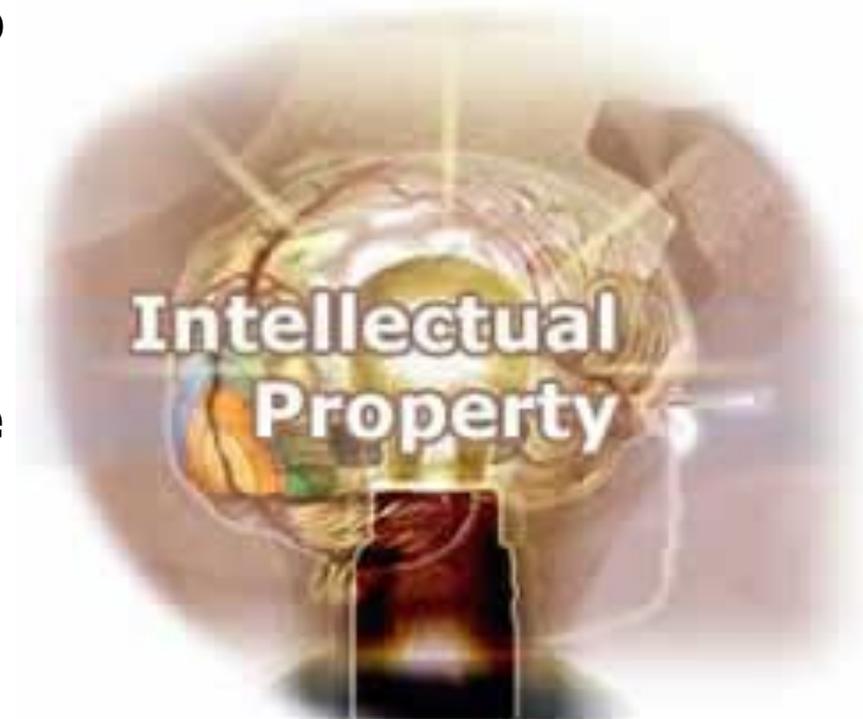
Reduce

Reduced Costs

Reduced Carbon Footprint

Intellectual Property Sharing Framework

- **Foreground (new) IP – ownership decided between parties participating in GreenTouch Research**
- **Foreground IP licensed to active GreenTouch Members royalty free for GreenTouch Research only**
- **Obligation to license Foreground IP for non-GreenTouch Research purposes**



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