Energy Efficient Wireless Networks Beyond 2020

ITU-R Workshop on “Research Views on IMT Beyond 2020”

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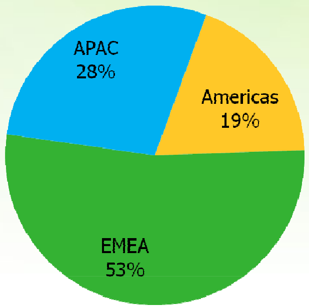
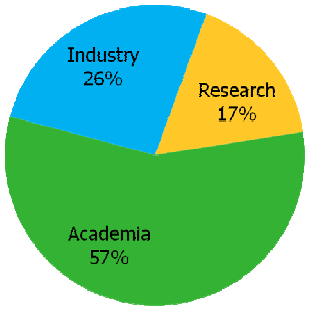
GreenTouch (www.greentouch.org)

Deliver Architectures, Specifications and Solutions and Demonstrate Key Technologies to Increase Network Energy Efficiency by a Factor 1000 Compared to 2010

- Bell Labs Initiated Global Research Consortium representing industry, government and academic organizations
- Launched in May 2010 with focus on energy efficiency, sustainability and growth
- Holistic and ambitious goal of 1000x
- Moving from fundamental research into the pre-competitive area through standardization
- 53 member organizations with 350+ leading scientists
- New innovation and collaboration model for R&D
- Recognized by the World Economic Forum as an industry-led best practice toward sustainability
- Leading Green ICT: cooperation with other organizations and NGOs such as GeSI, GreenGrid, Carbon Trust, ITRS



Membership by Region



Membership by Category

Consumer Expectations

Global Users

Anywhere, Any Time, Any Device

Wirelessly Connected

Video, HD, 3D, M2M …

Future Networks: What It's All About

Improve performance for the customer

- Connect consumer to information and knowledge truly everywhere
- Meet expectation of particular application and service
- Provide better battery life

Enable new applications and services

- Support different application needs (broadband, dense crowds, mission critical, machine type)
- From big data (video downloads) to small data (sensors)
- From consumers to machines and devices

Make the network more agile and flexible

- Improve end-to-end performance
- Adapt the network to the users and expectations
- Improve overall energy consumption

Key Challenges for Future Networks

How to provide a communication service that:

- Adapts to consumers
- Connects consumers and devices to services, applications and ultimately information

How to provide the services in the most efficient way?

- Total cost of ownership
- Operational expenses, including energy consumption

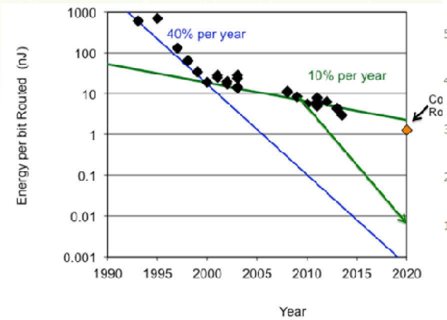
Energy is a key industry challenge

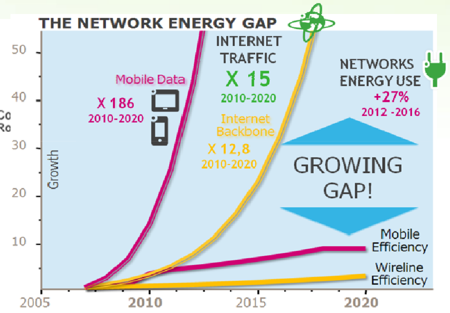
- Traffic growth without exploding energy consumption
- Services without access to reliable power grids

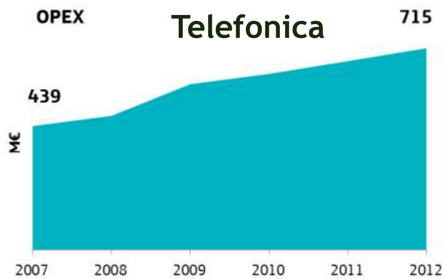
Energy Is An Industry Challenge

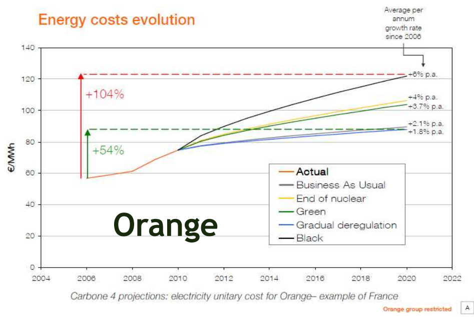
"This is a wake-up call to the industry. Energy consumption is not under control."
-- Vivek Badrinath, Deputy CEO Orange

- Exponential Traffic Growth
- Large Scale Deployments
- Rural and Off-Grid Deployments
- Technology Limitations
- Operator Energy Bills
- Cost of Energy Increasing
- Policy and Regulatory Pressure
- Marketing and Corporate Social Responsibility
- Environmental Impact

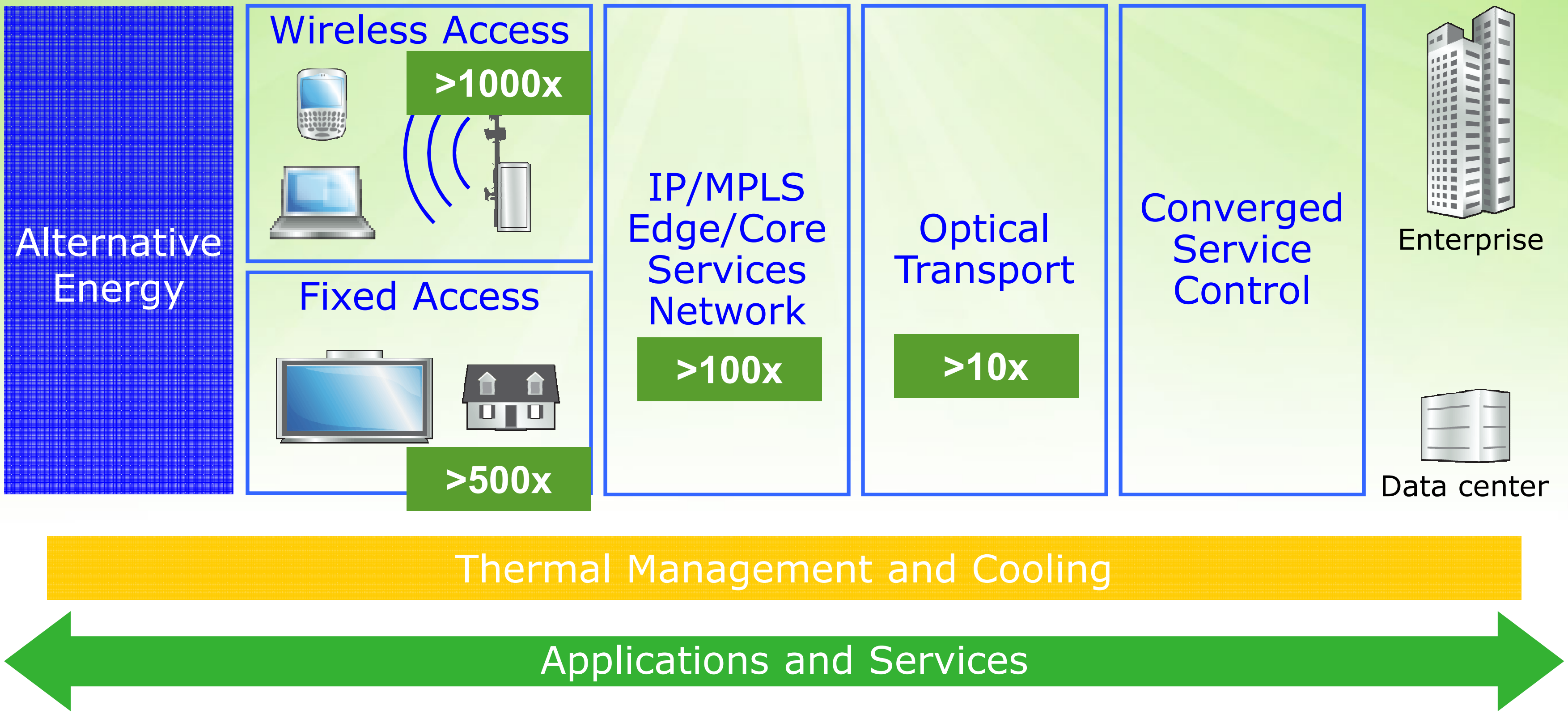






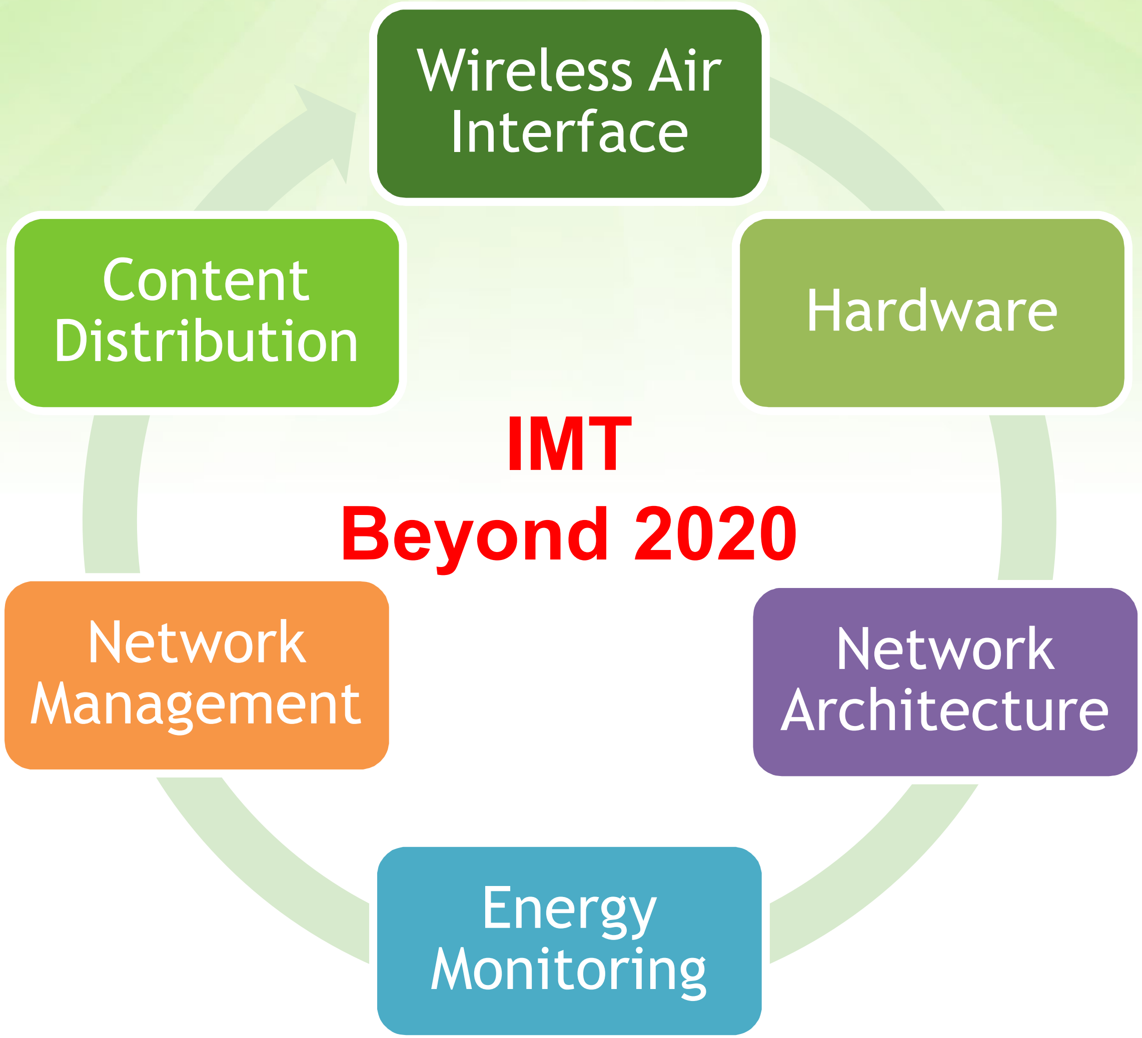


End to End Network Energy Efficiency



- Need to consider overall energy efficiency in the end to end network
- Larger energy gain and improvement opportunities in the access network, primarily the wireless access
- Optimize content and information storage and processing

Key Dimensions for Energy Efficient Mobile Communications

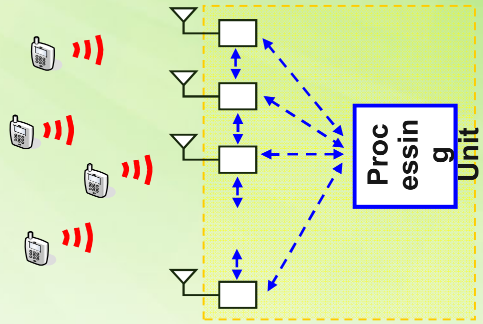


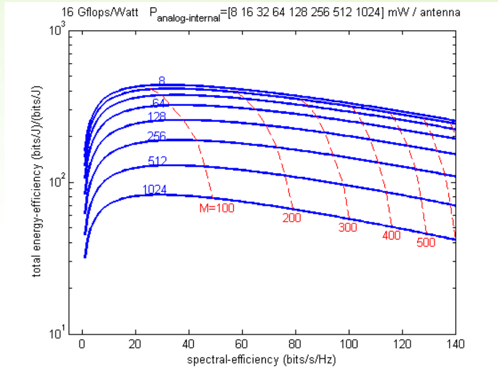
Wireless Air Interface

- **Large Scale Antenna Systems / Massive MIMO**
  - Tremendous spectral efficiency and energy efficiency gains
  - Applicable to high user densities and low mobility scenarios
- **Bandwidth Expansion and Low SNR Transmissions**
  - Power reduction due to bandwidth expansion
  - Fundamental tradeoffs between spectral efficiency and energy efficiency and between power and delay
- **New Waveforms**
  - Sharper frequency domain roll-off and reduced guard band
  - Lower PAPR
  - Support short information packets
- **Higher Frequencies / mm-Wave Access Technologies**
  - 30-300 GHz for short range and very high data rates in indoor / outdoor scenarios

Large Scale Antenna System

- Use many more service-antennas than terminals
- Directed data beams on down-link and selective reception of up-link transmissions
- Optimized LSAS provides dramatic gains in:
  - Radiated and total energy-efficiency (bits/Joule)
  - Net spectral-efficiency (bits/second/Hz)
- Doubling the number of service-antennas doubles the radiated energy-efficiency
- Account for 3 types of power consumption in total energy efficiency calculation:
  - Radiated power
  - LSAS-critical computing processing power
  - Internal per-antenna power consumption (RF chains, analog blocks, A/D)
- All complexity at the base station





Source: GreenTouch LSAS Project

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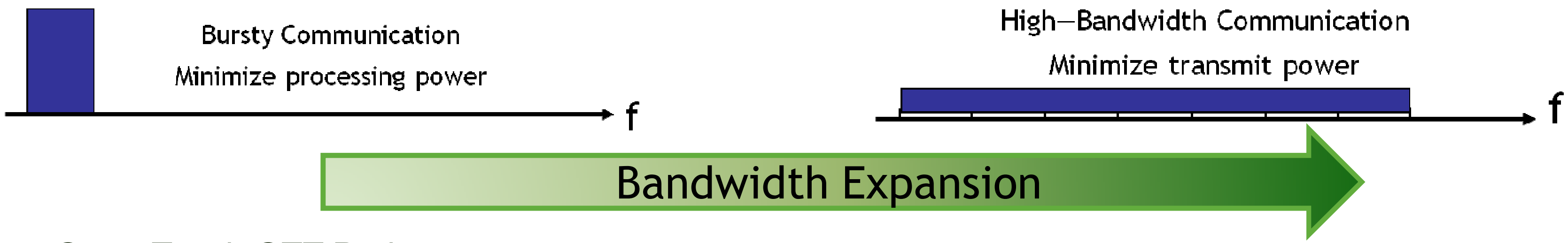
Bandwidth Expansion and Low SNR Transmission

- Insight from Shannon:
  - Larger bandwidth -> Lower transmit power
  - Fundamental tradeoff between spectral efficiency and energy efficiency
- Approaches:
  - Bandwidth expansion
  - Advanced technologies to better utilize bandwidth
- Tradeoff between transmit power and processing power
- Optimal bandwidth and system parameters for total energy efficiency

Interference-Limited Region
- Advanced radio transmission technologies
- Dynamic resource management strategies
- Cross-layer design for multi-user/multi-cell scenarios

Noise-Limited Region
- Very-low-rate coding schemes
- Novel PHY layer functions in low-SNR region
- Novel hardware designs

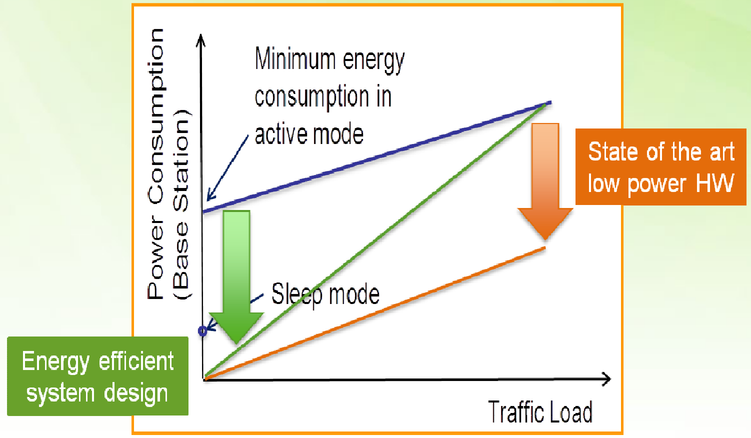


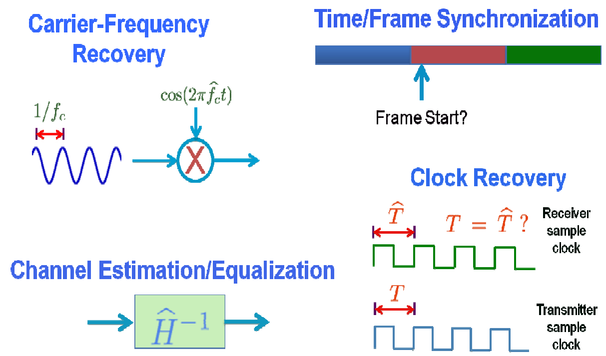
Source: GreenTouch GTT Project

Energy-Optimized Hardware

Hardware

- **Low power / energy efficient devices and hardware**
  - State of the art low power design
  - Energy efficient components
  - Reduce idle mode power
  - Achieve full energy-load proportionality
- **New hardware system design for MM-wave and LSAS**
- **Ultra wideband radios for low SNR operation**
  - Multiband and flexible spectrum allocation
  - New carrier / phase / time synchronization for large BW systems



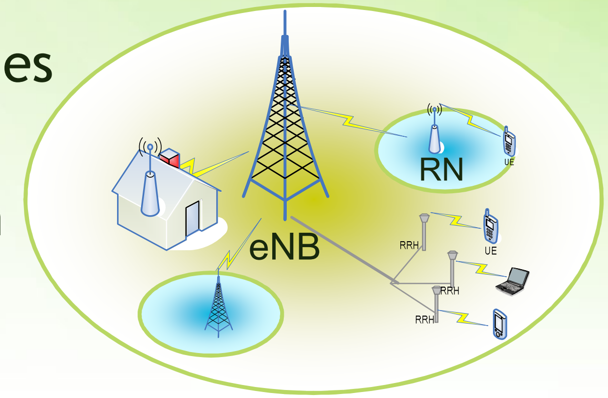


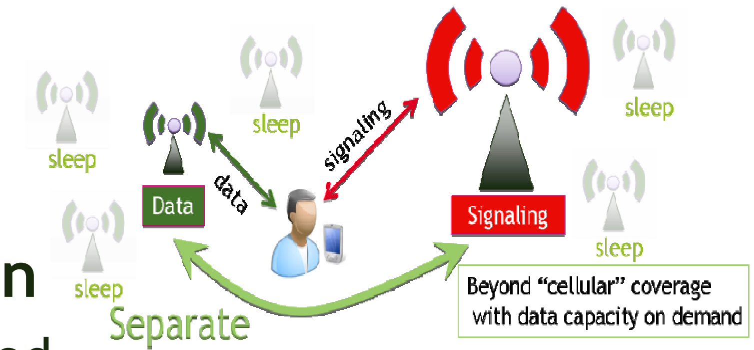
Source: CEET / U of Melbourne

Beyond Cellular Networks

Network Architecture

- **Heterogeneous access networks**
  - Extreme deployments of small / atto cells
  - Integrated and optimized multi-RAT technologies
  - Multi-hop and relaying
  - Opportunistic device-to-device communication
- **Separation of control and data plane functionalities**
- **Cell-free cooperative radio access network**
  - Simplifies mobility management
- **Connectionless data communication**
  - Eliminate elaborate signaling for enhanced support of devices with short data bursts



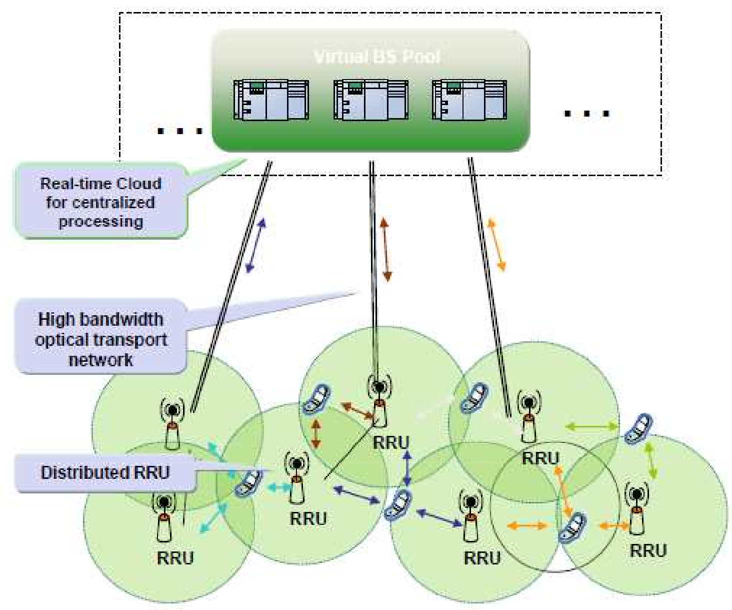


Source: GreenTouch BCG Project

Software Defined RAN (SD-RAN)

Network Architecture

- **Extension of SDN and NFV for wireless access and mobile communications**
  - Flexible access network to meet needs of different services and mobility
  - Logically centralized control of access (and transport and core) networks
  - Pooling of processing and coordination across many sites
  - On-demand, scalable and dynamic allocation of resources
  - Lower operational expense, faster system roll-out, upgrade and maintenance
  - Reduced processing in end nodes enables cheaper and less energy-hungry deployments

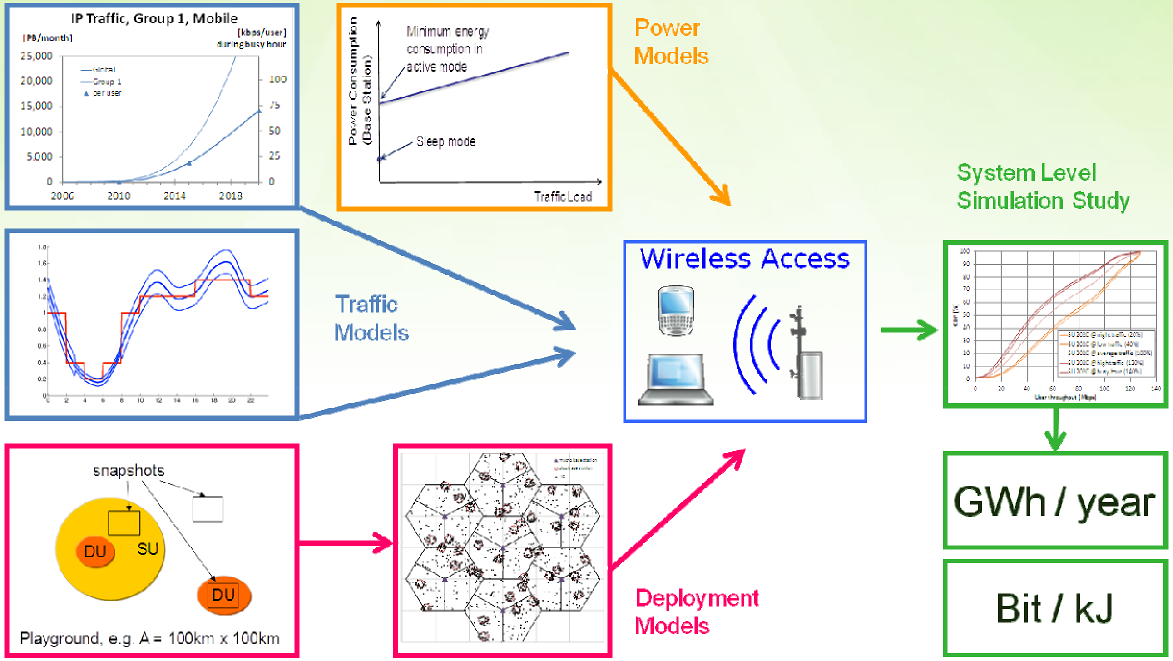


Source: China Mobile

Energy Assessment Methodologies

Energy Monitoring

- **Detailed system level modeling and energy consumption evaluation / simulations**



- **Real-time energy monitoring and dynamic control**
  - Component, subsystem and network element level
  - System-wide monitoring and control

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Network Management

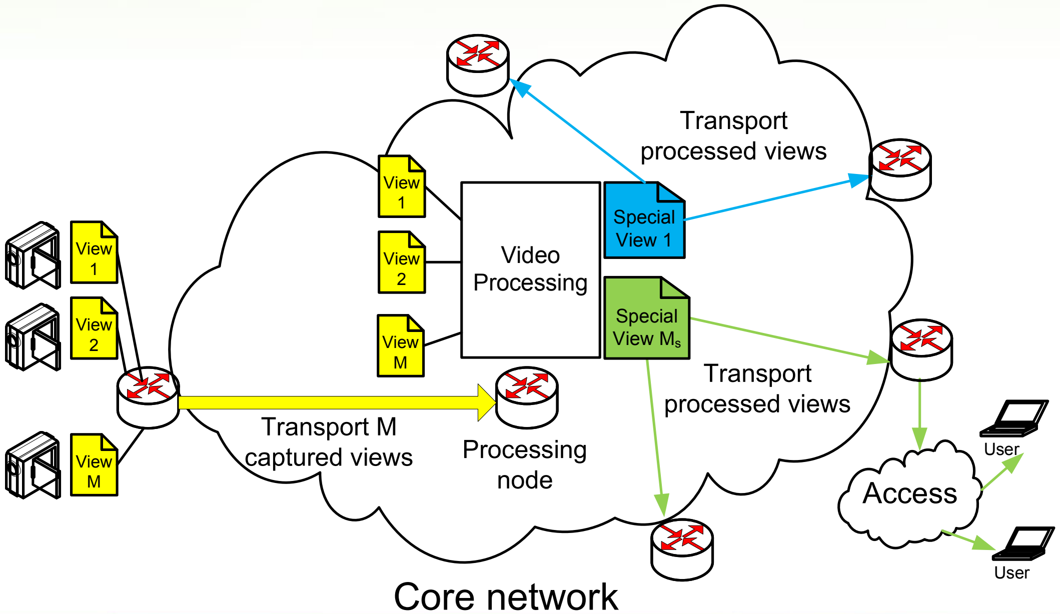
Network Management

- **Smart network resource management**
  - Fast timescale to match traffic patterns and service demands
- **Energy-load proportionality**
  - Energy consumption and resource utilization should track traffic load
  - Including zero power at zero load
- **Improve system energy efficiency by optimizing:**
  - Bandwidth and power allocation
  - Number of active antenna, active RF chains and resource blocks
  - Cell size and cell on-off switching
  - Intelligent collaboration schemes and joint transmission schemes
  - Processing resources
  - Joint transmit and processing power optimization

Content Distribution

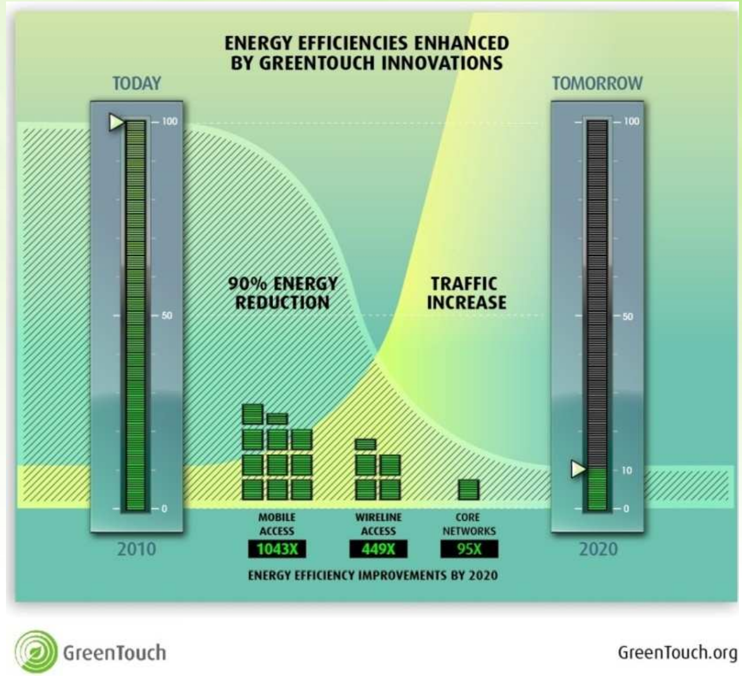
Content Distribution

- **Optimized in-network content caching and processing**
  - In access, metro and core networks
  - Down to access nodes and end-user devices
- **User, application and context-aware pre-loading, off-loading and load-balancing strategies**
- **Opportunistic use of device-to-device communication**



Energy Efficiency Improvement Opportunity

- Portfolio of described technologies contributing to objective of:
  - Reduced energy consumption
  - Sustainable IMT
- Initial “Green Meter” study on subset of technologies:
  - Quantifies overall energy efficiency gains
  - Relative impact of different technologies
  - Shows potential net energy reduction of 90% while supporting traffic growth
- More research needed to validate technologies and quantify energy gains
- Opportunities for new ideas



Webcast and GreenTouch White Paper June 2013

Conclusion

- A lot of challenges for IMT Beyond 2020
- Energy efficiency and energy consumption should be engrained in design consideration
  - Should always include energy considerations when studying new features and architectures
  - To ensure that improved performance is still sustainable
- Overview of several promising technologies
- Applicable efficient deployments in mature and developing markets
  - With available grid power
  - Off-grid / bad-grid power
  - Enable greater use of renewable energy sources

More research needed to validate technologies for "beyond 2020 IMT networks" and quantify energy gains