

Green Radio in Future Internet

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Introduction

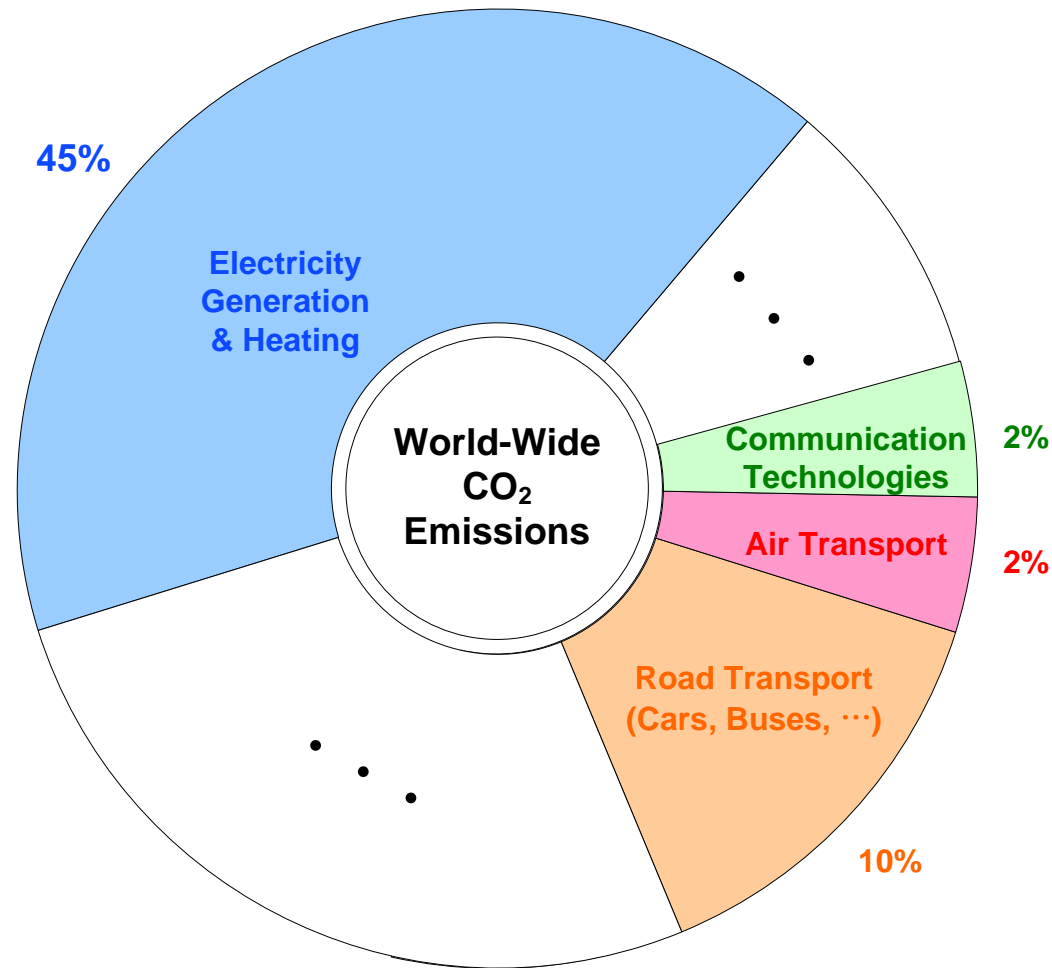
Green Radio?





Introduction

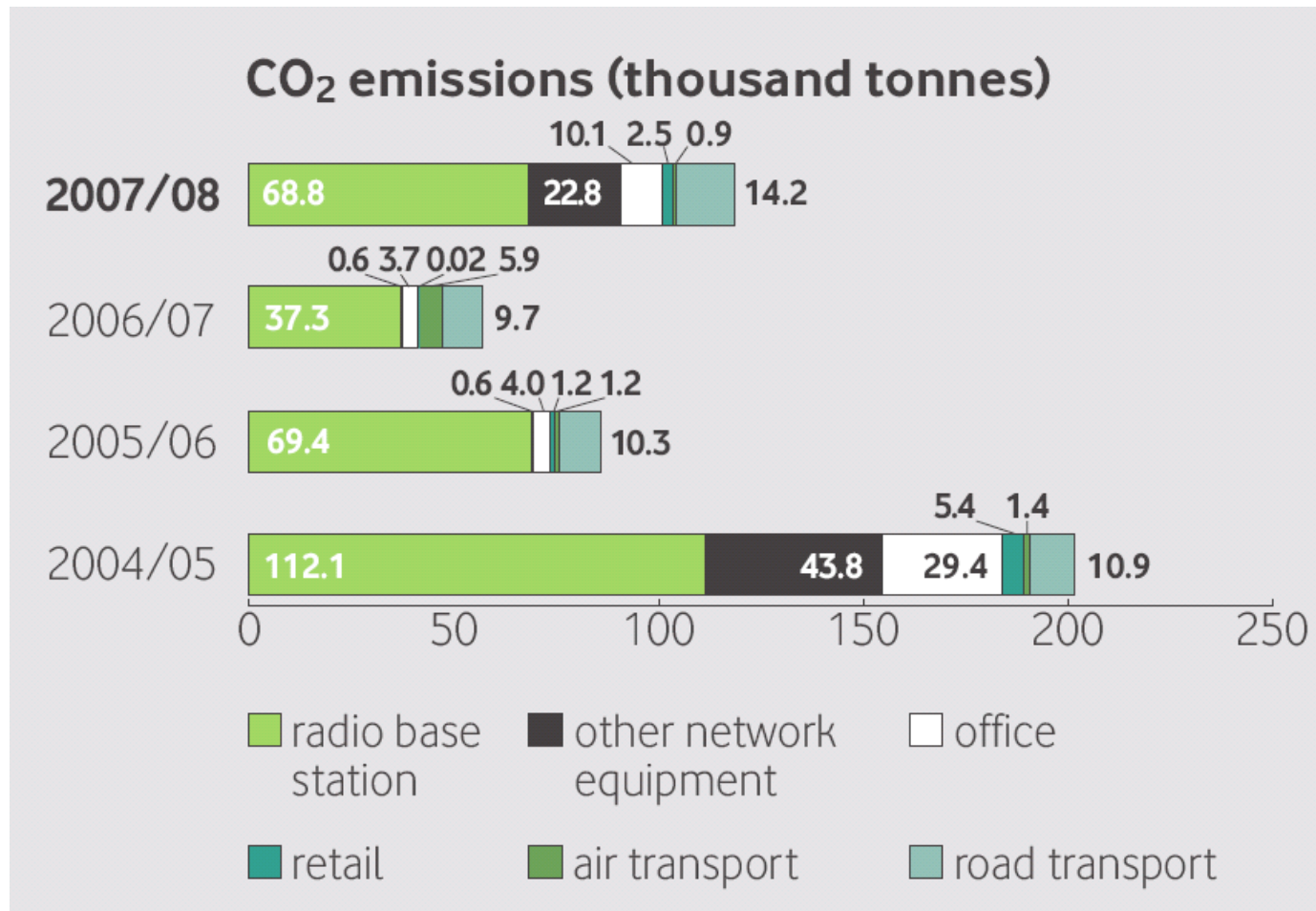
World-wide CO₂ Emissions





Introduction

CO₂ Emissions – In case of Vodafone UK

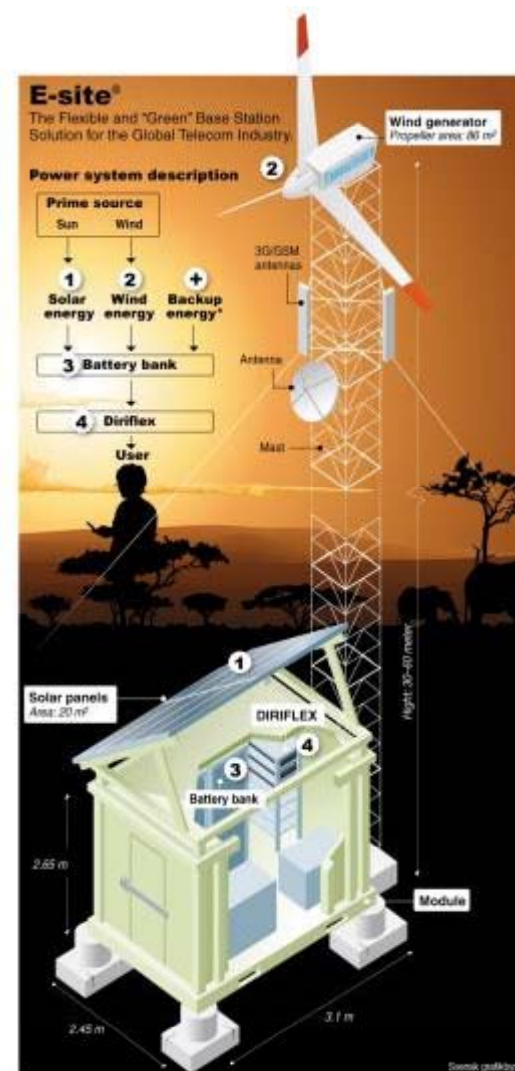
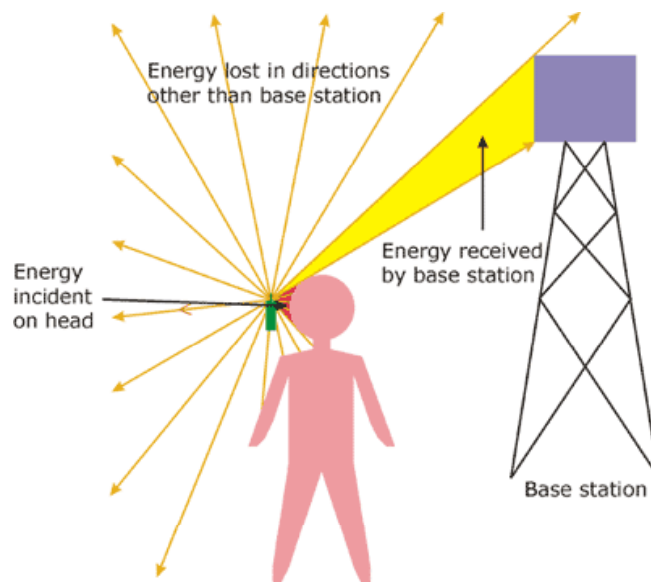


Needs for Energy-efficient information & communication technologies

Green Radio

Concept of the Green Radio

- Environmental-friendly
 - CO2 emissions
 - Human-body radiation
- Energy-efficient
 - Operations
 - Manufacturing

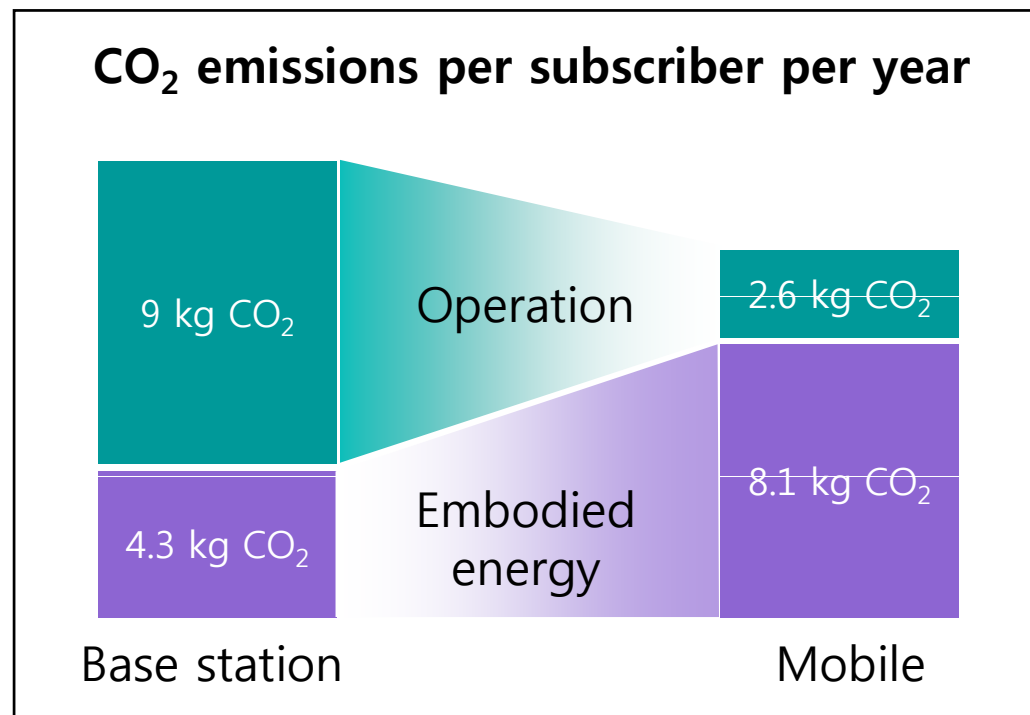




Green Radio

Power Saving and Green Radio

- Traditional power saving
 - Mobile terminals
- Green radio
 - Base stations, backhaul network, manufacturing process...





Green Radio

Collaborative Research Activities

- Mobile VCE – Green Radio
 - Industry steered
 - UK government funded
 - 3 year project, 2008-2011



Industry Steering Group



Academic Delivery Team





Green Radio

Research Challenges – Architecture

- Establishing baselines
 - Clear understanding of energy consumptions and the network elements
- Backhaul options
 - The best backhaul strategy for a given architecture
- Deployment scenarios
 - What is the optimum deployment scenario for a wide area network



Green Radio

Research Challenges – Architecture: Details

- Energy metrics & models
 - Energy metrics to accurately quantify consumption
 - Energy consumption models for the RAN architecture
- Energy efficient architectures
 - Large cell vs. small cell deployment
 - Assess scenarios for placement of relay nodes
- Multi-hop routing
 - Bounding energy requirements by strict end-to-end QoS
 - Exploiting user mobility for energy reduction
- Frequency management
 - Dynamic spectrum access to minimize energy consumption by utilizing bands with low interference
 - Solar-powered relaying allocating resources to match weather patterns



Green Radio

Research Challenges – Techniques

- Overall base station efficiency
 - Improvements in overall efficiency, measured as RF power out to total input power
- Improving the QoS/RF power ratio
 - Reducing the required RF output power maintaining the required QoS
- Scaling of Energy Needs with Traffic
 - Sleep mechanisms for base stations with no loads and techniques that allow power consumption to scale with load



Green Radio

Research Challenges – Techniques: Details

- Advanced base station architectures
 - Multi-mode and multi-standard
 - Base station re-use
- Integration allows energy reductions
 - Masthead electronics avoids cable losses
- Advanced power amplifier techniques
 - Develop envelope tracking method
- Interference minimization and cancellation
 - Making transmissions more robust to interference



Green Radio and Cognitive Radio

Green Communications and Green Spectrum: Is Cognitive Radio an Enabler or Anyone else?

- Panel discussion in CrownCom 2009
 - Honggang Zhang (Zhejiang Univ. CHI), Jacques Palicot (Supelec, FRA)
 - Discussion issues
 - Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)
 - An Approach for Realizing Future Internet with Cognitive Technologies (Wolfgang König, Alcatel Lucent)



Green Radio and Cognitive Radio

Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)

- Main contribution
 - Providing a variable power/bandwidth efficient modulation strategy
- Energy efficient green radio is...
 - Environmentally friendly
 - Permits the use of smaller batteries
 - Allows for a radio to transmit higher amounts of data



Green Radio and Cognitive Radio

Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)

- Bandwidth efficient vs. Energy efficient

Modulation Schemes	BPSK	QPSK	16 QAM	64 QAM
Code Rate	3/4	3/4	3/4	1
Target SINR (dB)	3.8	6.8	13	26
Spectral Efficiency (bps/Hz)	0.75	1.5	3	6

- Shannon Capacity

$$\text{➤ } C = \log(1 + \text{SINR}) \quad (\text{bps/Hz})$$


→ Tradeoff between bandwidth efficiency and energy efficiency



Green Radio and Cognitive Radio

Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)

- Variable power/bandwidth efficient modulation strategy
 - Power efficient (PE) system tries to use BPSK, unless the target traffic rate cannot be met with BPSK

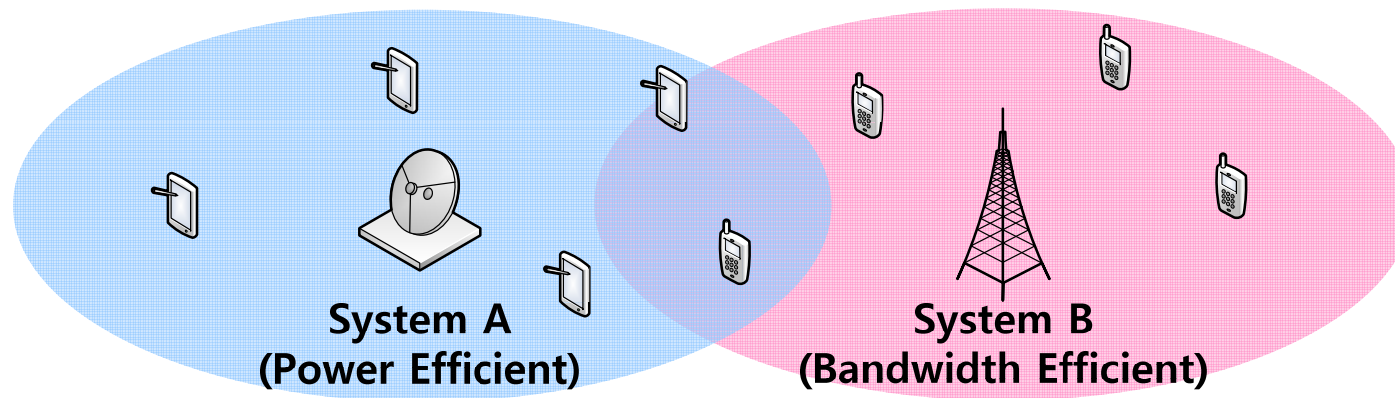
Primary User Occupancy Probability	Modulation Schemes for Cognitive System	Efficiency Strategy of Cognitive System
$P < 20\%$	BPSK	Power Efficient  Bandwidth Efficient
$P < 40\%$	BPSK, QPSK	
$P < 60\%$	BPSK, QPSK, 16 QAM	
$P \geq 60\%$	BPSK, QPSK, 16 QAM, 64 QAM	



Green Radio and Cognitive Radio

Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)

- System model



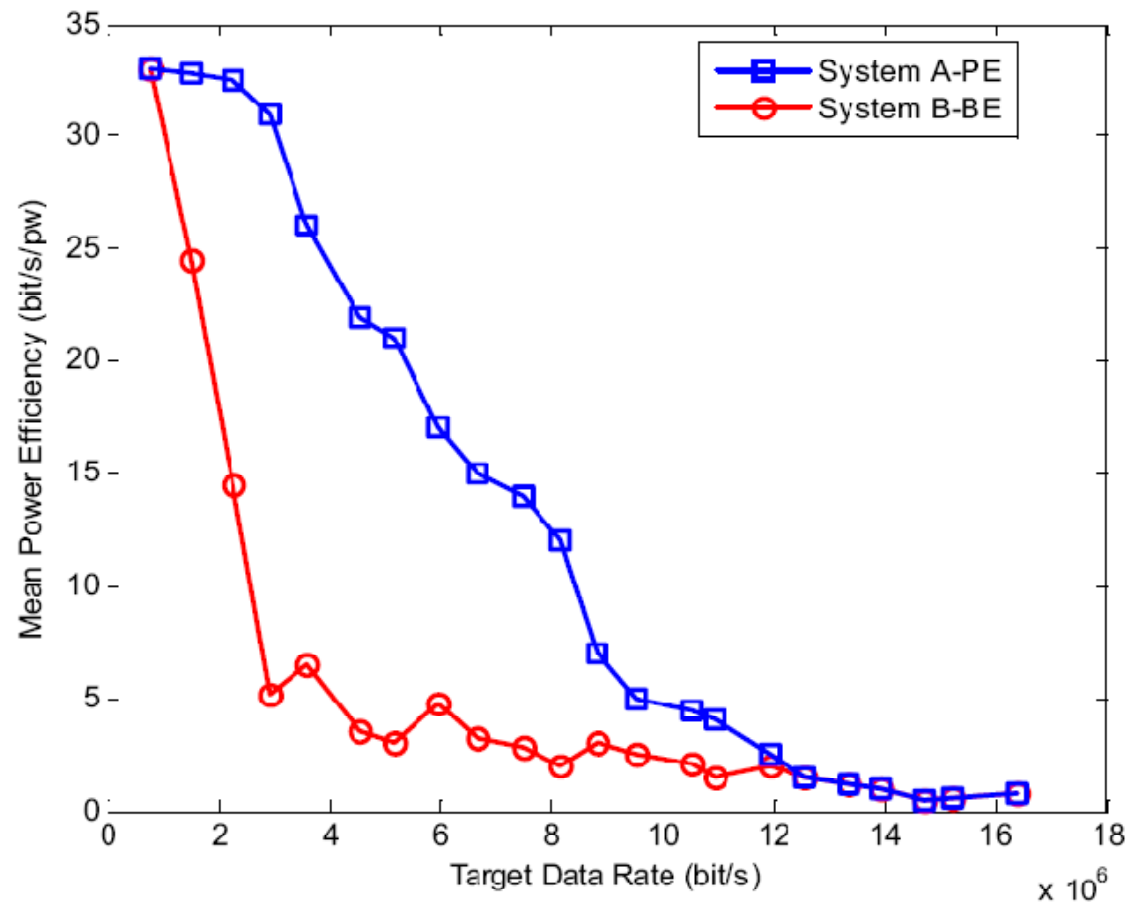
- Power efficient strategy
 - Modulation scheme depends on
 - » Target data rate
 - » Occupancy probability of system B
- Bandwidth efficient strategy
 - Choose the modulation scheme with the highest order



Green Radio and Cognitive Radio

Using Cognitive Radio to Deliver 'Green' Communications (David Grace, Univ. of York)

- Simulation results





Concluding Remarks

Green Technologies

- Relevance to business and politics will only continue to increase
- Green Radio offers timely industry driven research.

Green Radio Provide Insights of Value to...

- Operators considering the impact of Green for future network deployments
- Equipment vendors for identification of key techniques enabling green solutions.

Thank You!

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