Reducing Energy Consumption of Wireless Communications

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Abstract— **Wireless communications has been recognized as a key enabler to the growth of the future economy. There is an unprecedented growth in data volume (10x in last 5 years) and associated energy consumption (20%) in the Information and Communications Technology (ICT) infrastructure.**

The challenge is how to: meet the exponential growth in data traffic, deliver high-speed wide-area coverage to rural areas, whilst reducing the energy consumed. This paper focuses on the cellular wireless communication aspect, which constitutes approximately 11% of the ICT energy consumption. The paper shows that with careful redesign of the cellular network architecture, up to 80% total energy can be saved. This is equivalent to saving 500 TWh globally and 1.4 TWh in the United Kingdom.

I. Introduction

A. ICT Energy Consumption

Currently, the energy story as shown in Fig. 1 is as follows:

- 0.5% of the worlds total energy is consumed by wireless communications, equivalent to 650TWh (35 2000MW power plants).
- Over 90% of this energy is consumed in the outdoor cellular network, of which 75% is consumed by base-stations.

In terms of digital connectivity, approximately 70% of the developed world and less than 20% of the developing world is digitally connected [1]. Yet, the volume of data communication has increased by more than a factor of 10 over the past 5 years. To foster economic growth and reduce the wealth and knowledge gap: a low energy solution that can increase connectivity and meet the growing data demand must be found.

This paper outlines solutions that can increase network capacity, extend coverage to communities without access, whilst reducing the energy consumption significantly. Moreover, the investigation considers energy harvesting techniques that can further reduce the energy consumption of the network. The key research question this paper addresses is: **Given a *dynamic* environment, can a low energy wireless network be developed to deliver the same service as the conventional network?**

B. Investigation Methodology

The experiment is conducted using a proprietary simulator (VCESIM) developed at the University of Sheffield for the MVCEs industrial and academic members. The simulator considers:

- User Mobility and Traffic Modeling
- Multiple Cells with Antenna Height and Radiation Patterns
- Full Interference Modeling
- Scheduling
- Realistic basestation Power Consumption Models with backhaul

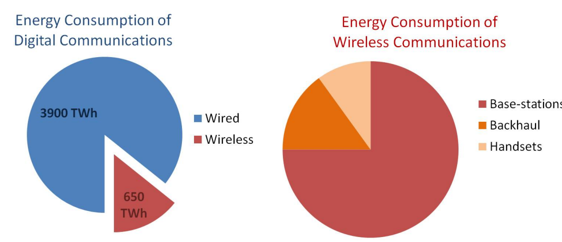

Fig. 1. Energy Consumption of Wired and Wireless Digital Communications as of 2008-2010. A single UK cellular network typically consumes 40MW.

II. Expanded Mobile Network

A. 3G to 4G Migration

The current 3rd Generation (3G) network is based on spread spectrum technology and operates in a 5MHz band. This is known as the High-Speed-Packet-Access (HSPA) Network. Ofcom plans to sell up to 20MHz of new bandwidth for the 4th Generation (4G) network, some made available from Analogue-Digital switch-over. The 4G cellular network is known as the Long-Term-Evolution (LTE). The improved spectral efficiency due to spectrum access technologies and increased bandwidth allows up to 70% capacity improvement [2] and 35 to 50% energy reduction [3].

B. Urban Capacity and Rural Coverage

The paper improves the new 4th Generation mobile network by increasing capacity, extending coverage and reducing energy consumption, as shown in Fig. 2:

- **Urban Capacity Improvement**: Self-organizing indoor femto-cell access-points, wireless relays and dynamic cell-sites.

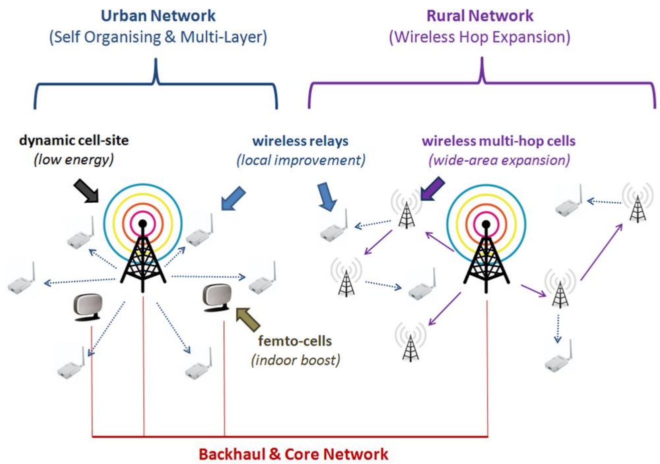

Fig. 2. Advanced 4G LTE-A Architecture for Urban and Rural environments.

- **Rural Coverage Extension**: Wireless multi-hop small cells and relays that employ dynamic sleep mode and energy harvesting techniques.
- **Total Energy Saving**: Aim to reduce energy consumption by 99%, so far 84-92% has been achieved.

C. Dynamic Cells

The main contribution of the paper is to examine how the deployment architecture can be improved to reduce energy consumption whilst maintaining quality of service. In Fig. 3a the reference LTE deployment is shown. As relays are introduced, the number of cells can be reduced, saving operational energy consumption of the network by approximately 50%, as shown in Fig. 3b. Further optimization of techniques can reduce the number of cells further.

As the traffic load can vary by as much as 4 folds during the course of the day, a challenge is how to scale the energy consumption with the traffic load efficiently. The reference network can reduce the energy consumption by up to up to 30% at low loads. The technique of reducing cell-sectors and antenna pattern switching, shown in Fig. 3c can reduce energy by an additional 10% at low loads.

D. Energy Story

The emerging energy story is that there are two dimensions to consider when deploying a new low energy network: peak traffic value and dynamic variation of this traffic load. The research combines the techniques of 4G, cell deployment, relays and dynamic cell changes to create a low energy architecture. The resulting energy saving achieved at the low load scenarios is 77%; and the least energy saving (60%) is achieved at the high load scenario of a peak traffic profile.

III. Conclusion

This paper has shown that the same wireless information exchange rate can be achieved with significantly less energy consumption (77% reduction). The impact this has on the digital society and economy is that increased volumes of data transfer in the future can consume a reduced amount of energy. Currently, the proposed solution can save up to 500TWh globally and 1.4TWh in the UK. This saving is set to rise by 200% in the next decade, which amounts to the equivalent of saving 40% of a typical UK nuclear power plant.

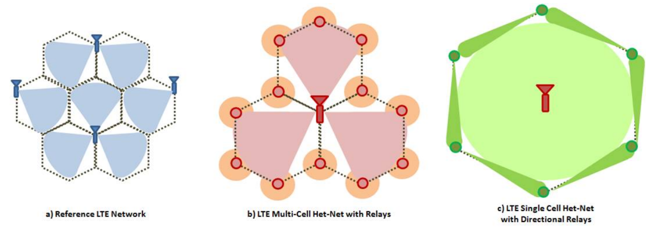

Fig. 3. Reference and Dynamic Deployments: a) Reference micro-cell deployment; b) Macro-sectorized-cell deployment with low power relays; c) Macro-single-cell deployment with high power directional relays.

Acknowledgement

The work papered in this paper has formed part of the Green Radio Research Programme of the Virtual Centre of Excellence in Mobile and Personal Communications, Mobile VCE. Fully detailed technical papers are available to Industrial Members of the Mobile VCE. www.mobilevce.com

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Weisi Guo received his MEng, MA and PhD degrees in Engineering from the University of Cambridge. He has worked in Deutsche Telekom's T-Mobile International and currently works at the University of Sheffield. His research interests include energy efficient and cooperative techniques for wireless communications. He is the winner of the EPSRC Young Millennium Scientist Award and the author of the VCESIM Simulator.

Tim O'Farrell is the Chair in Wireless Communication at the University of Sheffield and the Academic Coordinator of the MVCE Green Radio Project. His research activities encompass resource management and physical layer techniques for wireless communication systems. He has led over 18 major research projects and published over 230 research outputs, including 8 patents.