Chapter 28
Green Communications: Realizing Environmentally Friendly, Cost Effective, and Energy Efficient Wireless Systems

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ABSTRACT

The exponential growth of wireless systems makes their carbon footprint hard to ignore. This chapter presents statistics related to the energy consumption of cellular networks' infrastructure in order to motivate the need for more efficient and environmentally friendly communications. A definition of the term "Green Communications" is provided along with different metrics that can be used to quantify energy efficiency for the various aspects of wireless infrastructure. In addition to topics related to cellular infrastructure, the chapter presents a brief review of key techniques that can be potentially used for improving energy efficiency. Furthermore, since improving energy efficiency is not by itself sufficient for low-carbon systems, possible ways of using and managing energy harvested from renewable sources such as solar and ambient RF signals are discussed. Moreover, the concept of Wireless Distributed Computing is introduced to illustrate how a group of wireless devices can share their resources for achieving a set of common goals. Finally, resource allocation is examined for managing the trade-offs involved when simultaneously minimizing the carbon footprint and performing the necessary communication and computation tasks in mobile devices.

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INTRODUCTION

The intersection of three undeniable trends, namely escalating energy costs, future uncertainty in the availability of fossil fuels and accelerated rise in communications usage, creates an urgent need to address the development of energy-efficient and environmental-friendly communications. The cellular radio network is the largest factor contributing to the mobile industry's environmental impact (Lamour, 2008) with the emissions from the telecommunications business sector estimated at between 0.5% (Fettweis & Zimmerman, 2008) and 1% of the whole world's carbon footprint (Singh, 2008). While this may seem trivial, the seriousness of the issue is more apparent from the perspective of energy costs. In some telecommunications markets, energy-related costs account for as much as half of a mobile operator's operating expenses (Ericsson, 2008). The expectation that energy costs may rise three times over the next seven years is cause for serious concern (Fettweis & Zimmerman, 2008). In addition, with respect to future predictions of the depletion of fossil fuel reserves, it is necessary to minimize the dependence of communication networks on non-renewable energy sources, considering the critical importance of communications in economic growth and national security. Recently, the term "Green Communications" has been marketed as a solution to addressing the growing cost and environmental impact of telecommunications.

There are several hurdles that must be overcome in order to achieve green communications. The current design paradigm focuses on different levels within the network protocol stack, and there is a disconnect between issues concerning the hardware platform and software framework for network communications. Additionally, deployment, operations, and peripheral elements, such as air conditioning and fuel transportation, are further disconnected from the original component and system design cycle. This compartmentalized thinking severely limits truly transformational benefits. Currently, most advancements in energy-efficient communications focus within a narrowly defined aspect of the communication system, such as power amplifier design or incorporation of renewable energy sources. In addition, there is a lack of explicit energy efficiency definitions and metrics for wireless telecommunications to provide a solid foundation for assessing the overall improvement and quantification of Green Communications.

Contrary to conventional approaches to communications system design, this chapter aims to provide an overview of unique methods that can be used for achieving truly environment-friendly communications. Specifically, the chapter adds a level of formalization to the term "Green Communications" and addresses fundamental hurdles to realizing overall improvements in communication system design. In addition, this chapter contrasts and provides a survey of existing definitions and metrics in energy efficiency, and their applications towards green communications. Finally, the chapter provides a survey of key methods that can be used to achieve green systems with wireless capabilities.

The remainder of this chapter is organized as follows: Section "The Need for Green Communications" highlights current energy usage and costs associated with telecommunications, and places these statistics into perspective by comparing with other aspects of our daily life. Section "Envisioning Green Communications and quantifying its impact" defines our vision of a green communications system, reviews and discusses existing metrics for power and energy efficiency, and identifies requirements for telecommunications specific metrics. Section "Survey of Potential Solutions" provides a brief survey of various techniques that can be used to improve energy efficiency in wireless networks.