Abstract

Demographic trends are leading everywhere to increasing health care costs, fewer hospital beds, and shorter hospital stays. Consequently, families are now expected to supply a longer and more sophisticated level of care at home. However, family resources are also declining as members live further apart and fewer people choose to stay home full-time. These developments are increasing demand for new technologies that move health care out of the hospital while minimizing pressure on the family and community.

Wireless body area networks (WBANs) have recently been proposed to meet this demand. Small sensors worn on the body collect relevant health information and send the data to a portable device, such as a cell phone. The central device can warn the patient in advance of an important event, such as a seizure, or signal other sensors to automatically administer medication, such as insulin for diabetics. Otherwise, it can store the information while continuously monitoring health indicators. When necessary, data can be sent through the existing communication infrastructure for later analysis by a doctor or to immediately call an ambulance during a medical emergency. Thus, body area networks have many potential applications related to remote patient monitoring, research, and early identification of chronic diseases.

At the same time, the growth of the internet, the commercial success of digital cellular phones, and the continuous scaling of integrated circuit technologies have lead to dramatic improvements and increasing popularity of wireless devices. To meet the requirements of future wireless services, regulatory agencies around the world have recently released an unprecedented amount of bandwidth spanning several gigahertz for license-free commercial applications employing a special form of communication called ultra-wideband (UWB). This newly allocated bandwidth promises to enable not only very high speed short-range communication, but also novel impulse radio designs that can reduce power consumption and cost.

Despite encouraging technological and regulatory developments, the full potential of emerging wireless sensor networks to personal health monitoring has never been realized. This is because, while traditional indoor and outdoor radio propagation has been studied extensively, the body area radio channel is still poorly understood making it impossible to precisely evaluate and study optimal WBAN communication systems.

To address this problem, we have derived an analytical model of body area propagation directly from Maxwell's equations. Using these insights, together with an extensive empirical investigation, we have developed a practical statistical body area propagation model useful for analyzing and evaluating the performance of both traditional narrowband and emerging ultra-wideband systems. Finally, we have used this model to show how a mostly-digital sub-sampling UWB radio architecture provides a promising and feasible solution for low power and low cost body area communication. This dissertation reports the results of this investigation demonstrating the potential of ultra-wideband wireless body area networks.