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Distributed Multi-Objective Resource Optimization for Mobile-Health Systems

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Mobile-health (m-health) systems leverage wireless and mobile communication technologies to promote new ways to acquire, process, transport, and secure the raw and processed medical data. M-health systems provide the scalability needed to cope with the increasing number of elderly and chronic disease patients requiring constant monitoring. However, the design and operation of such pervasive health monitoring systems with Body Area Sensor Networks (BASNs) is challenging in twofold. First, limited energy, computational and storage resources of the sensor nodes. Second, need to guarantee application level Quality of Service (QoS). In this paper, we integrate wireless network components, and application-layer characteristics to provide sustainable, energy-efficient and high-quality services for m-health systems. In particularly, we propose an Energy-Cost-Distortion (E-C-D) solution, which exploits the benefits of medical data adaptation to optimize transmission energy consumption and cost of using network services. However, at large scale networks and due to heterogeneity of wireless m-health systems, centralized approach becomes less efficient. Therefore, we present a distributed cross-layer solution, which is suitable for heterogeneous wireless m-health systems and scalable with the network size. Our scheme leverages Lagrangian duality theory and enables us to find efficient trade-off among energy consumption, network cost, and vital signs distortion, for delay sensitive transmission of medical data over heterogeneous wireless environment. In this context, we propose a solution that enables energy-efficient high-quality patient health monitoring to facilitate remote chronic disease management. We propose a multi-objective optimization problem that targets different QoS metrics, namely, signal distortion, delay, and Bit Error Rate (BER), as well as monetary cost and transmission energy. In particularly, we aim to achieve the optimal trade-off among the above factors, which exhibit conflicting trends.

The main contributions of our work can be summarized as follows:

(1) We design a system for EEG health monitoring systems that achieves high performance by properly combining network functionalities and EEG application characteristics.

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(2) We formulate a cross-layer multi-objective optimization model that aims at adapting and minimizing, at each PDA, the encoding distortion and monetary cost at the application layer, as well as the transmission energy at the physical layer, while meeting the delay and BER constraints.

(3) We use geometric program transformation to convert the aforementioned problem into a convex problem, for which an optimal, centralized solution can be obtained.

(4) By leveraging Lagrangian duality theory, we then propose a scalable distributed solution. The dual decomposition approach enables us to decouple the problem into a set of sub-problems that can be solved locally, leading to a scalable distributed algorithm that converges to the optimal solution.

(5) The proposed distributed algorithm for EEG based m-health systems is analyzed and compared to the centralized approach.

Our results show the efficiency of our distributed solution, its ability to converge to the optimal solution and to adapt to varying network conditions. In particular, simulation results show that the proposed scheme achieves the optimal trade-off between energy efficiency and QoS requirements of health monitoring systems. Moreover, it offers significantly savings in the objective function (i.e., E-C-D utility function), compared to solutions based on equal bandwidth allocation.