A Thesis for the Degree of Ph.D. in Engineering

Resource allocation and channel estimation techniques for OFDMA systems

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Abstract

Wireless communications are ubiquitous. People are no longer just checking email from wireless devices. Multimedia services are in very high demand, while the quality of multimedia services is increasing, the data transmission speeds are not advancing proportionately. This puts enormous pressure on the wireless service providers to constantly increase the throughput. The 4th generation wireless systems are been designed to address this throughput demand. Orthogonal-frequency-division-multiplexing (OFDM) technology is being chosen as one of the PHY/MAC layer of the 4th generation networks due to number of advantages it provides and high throughput being one of them. Although OFDM is able to provide increased throughput in theory, in practice it is difficult to achieve this limit. Resource allocation is the technique that allocates bandwidth, power, etc., to users, such that the system throughput is increased, while at the same time user quality-of-service (QoS) is maintained. In this dissertation we focus our study mainly on two areas related to the OFDM technology: resource allocation and channel estimation. Resource allocation is a fundamental process that basically allocates data bits to subcarriers. This is an important process since the bandwidth and power is limited, resource allocation algorithm needs to allocate as much data as possible, at the same time satisfying different constraints, including time constraint. Next we study the process of channel estimation in OFDM systems, since channel estimations, or users frequency responses, are the most important information for the operations in the PHY, including resource allocation. Resource allocation algorithms require, among other information, accurate estimations of users channels to make proper resource allocations.

Chapter 1 presents an introduction to the OFDM system with its theoretical background. The resource allocation fundamentals are presented with some simulation results showing the importance of proper resource allocation and also the nature of the complexity of the problem. We also introduce the channel estimation fundamentals of the OFDM system. Channel estimation is important in OFDM systems which use coherent demodulation, multiple-input-multiple-output (MIMO), antenna selection and many other techniques. Most of all, channel estimations are required for proper resource allocation. Resource allocation algorithms rely heavily on the channel estimations to allocate subcarriers, power, modulation and coding levels, etc., to achieve larger throughput and QoS. A discussion on importance of channel estimations and the complexity involved with the process is discussed here.

Chapter 2 presents our proposed low complexity resource allocation technique using a user ranking procedure to address the complexity issue of the channel estimation in OFDM systems,. This technique takes user channel characteristics into account and define several attributes. Fuzzy set theory is used on these attributes to prioritize the users. The proposed methodology is flexible in the sense that it can be used with different attributes to customize to the system parameters and required performance.

Chapter 3 explains the proposed steady-state Kalman filter for the channel estimation in OFDM systems. Conventional Kalman filters are used in OFDM systems for channel estimation due to their simplicity and the ability to operate in non-stationary environments. Nevertheless, Kalman filters are quite computationally complex due to a matrix inversion present in the calculation. In OFDM systems, channel estimations are required to perform in frequency domain and this could become a computational burden. The proposed steady-state Kalman filter uses channel and system characteristics to simplify the problem to a scalar level. In addition to reduced complexity, the steady-state Kalman filter is able to avoid the convergence period, and thus, providing better performance.

Chapter 4 presents a statistical analysis of the quantization noise present in an end-to-end OFDM link. Quantization noise is present in every digital communication system, and although the higher

resolutions of currently available quantizers are able to reduce the quantization noise to negligible levels, this higher resolution comes at a high power consumption cost. With newer systems integrating MIMO, the effect of power consumption of the quantizers are going to more severe as parallel radio-frequency (RF) links are required. Here we identify the effect of system model on the quantization noise. An analysis on howthe signal PDF is changing from the transmitter to the receiver end, and how it affects the quantization noise is given. This study is motivated by the Kalman filter channel estimation, where the noise statistics are treated as an important parameter that needs to be known.

Chapter 5 concludes this dissertation with an overall discussion of the OFDM techniques discussed.