

Multi-User OFDM in Mobile Multimedia Network

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INTRODUCTION

The optimization of resource allocation in multi-user orthogonal frequency division multiplexing (OFDM) has been of great concern to the mobile commerce. The major concern is the allocation of subcarrier and power to different users in order to minimize the total transmitted power, consequently increasing the total data rate and improving the performance of the wireless communication system. Multi-user OFDM systems have been in use recently and seem promising for future mobile network applications. This research would mainly focus on modeling and improving the wireless communication system with multi-user OFDM. The proposed optimization techniques for OFDM wireless communication will be conducted in two phases. Phase one is to optimize the subcarrier allocation to mobile hosts, and the second phase is to optimize the power allocation (depends on the number of transmitted bits) in a multi-user OFDM system.

A wireless and mobile multimedia network has become challenging in the cutting-edge technology of today's global market economy. Some current applications include mobile computing, mobile phones, satellite communications, radio stations, and so forth. An efficient communication plays a very important role in any wireless and mobile network. Global system for mobile communications (GSM) and code-

division multiple access (CDMA), commonly known as the second-generation (2G) mobile systems, are being widely used all over the world and have been constantly developing over the last decade (Zheng, Huang, & Wang, 2005). These developments have led to the growth of third-generation (3G) and fourth-generation (4G) mobile systems. Among the many technologies proposed for 4G systems, orthogonal frequency-division multiplexing (OFDM) has been of great interest over the past decade (Gross, Geerdes, Karl, & Wolisz, 2005). The major reason is that it can provide high data rates over a wireless channel and it divides the bandwidth into subcarriers (Gross et al., 2004).

OFDM is defined as a multi-carrier transmission technique that has been recognized as an excellent method for high-speed bi-directional wireless data communication. OFDM effectively squeezes multiple modulated carriers tightly together, thus reducing the required bandwidth. The modulated signals overlap with each other, but they do not interfere with each other since they are kept orthogonal (Intel in Communications, n.d.). Figure 1 shows a conventional frequency division multiplexing (FDM) with nine subcarriers using filters, while Figure 2 shows an OFDM with nine subcarriers. The quality remains the same, but the bandwidth required and consequently the cost has been reduced tremendously. Resource allocation problems are of

Figure 1. FDM with 9 subcarriers using filters (Intel in Communications, n.d.)

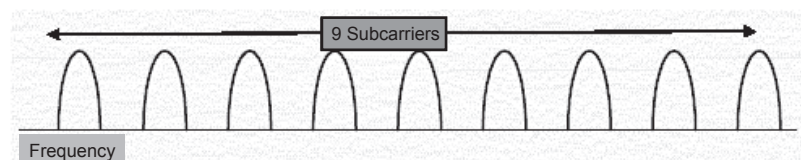
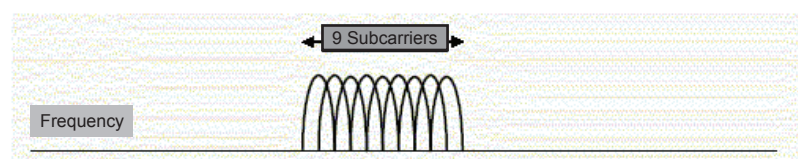


Figure 2. OFDM with 9 subcarriers (Intel in Communications, n.d.)



great concern to wireless communication networks dealing with a multiple-user OFDM system (Shen, Andrews, & Evans, 2003).

The major concern is the allocation of subcarriers and power to different users in order to minimize the total transmitted power, increase the total data rate, and maintain an acceptable quality.

BACKGROUND

Mobile and wireless communication networks are growing both in size and complexity and hence the use of OFDM has increased over the past few years. With this tremendous growth, engineers are facing challenges in deciding the allocation of subcarrier, bit, and power to multiple users in an OFDM system. While OFDM-based multi-user systems have been proposed, subcarrier and power allocation for these systems is still under investigation (Kivanc & Liu, 2000). The wireless communication network using OFDM is described as follows (Shen et al, 2003):

- OFDM divides the entire transmission bandwidth into a number of orthogonal subcarriers.
- The set of subcarriers is adaptively assigned to different users. Some subcarriers are inadequate for some users but good for others. Hence by adaptive assignment, we can ensure that all the subcarriers will be used effectively.
- The second issue would be to determine the power level transmitted on each subcarrier in order to minimize the total power transmitted (to reduce cost of transmission) and attain acceptable quality.

Since both the issues are correlated, they must be solved together using a single model (Gross & Karl, 2004).

The problem of optimizing subcarrier and power allocation in a multi-user OFDM system is studied by Kivanc and Liu (2000). Their work explains the importance of the problem and gives a detailed model for the problem. They define two greedy algorithms and claim that they give optimum solutions. The approach is appropriate, but a method such as a greedy algorithm does not guarantee an optimum solution, though the method has less computations and the solution is reached quite fast. The study also includes an application for a small-scale problem using Excel. Using integer programming would yield optimum results as compared to greedy algorithms. A similar approach has been conducted by Wong, Cheng, Letaief, and Murch (1999) and Kivanc and Liu (2000). However, Wong et al. (1999) developed an algorithm for a single-user system, and then they extended the algorithm for a multi-user system. The results are compared to other static allocation schemes and have proved the algorithm to be better than static allocation schemes. Another

approach developed by Shen et al. (2003) employs methods like Newton-Raphson and Quasi-Newton. The drawback of the method is the high complexity involved in the computations. Their primary focus is on proving a multi-user OFDM system to be better than the other conventional methods. Their secondary focus is on the optimization technique. Mohanram and Bhashyam (2005) have explored this area and have used suboptimal techniques to solve the problem.

Furthermore, integer programming could be used to solve the problem. In this proposal, the steps required in achieving the optimum solution using integer programming are analyzed. Integer programming gives us the optimal solution, unlike greedy algorithms. However, when the number of design variables increase (a large-scale system model), the time to solve the problem using integer programming is high, and at some point it becomes impossible to solve using integer programming. Thus, an alternate algorithm would be developed for the system, and this algorithm would be tuned to get the same solution as obtained with integer programming. This tuned algorithm can be used for larger models where integer programming could not work. A comparison would be done between the developed algorithm to the existing greedy algorithm in terms of optimality and number of iterations.

When an optimization problem has some variables that can be only integer, then integer programming can be used to achieve the optimum solution (Wolsey, 1998). Evidently, integer programming becomes complex when the number of design variables increase. However, the advantage as compared to heuristic algorithms is that integer programming results in optimum solution. Optimization deals with problems of minimizing or maximizing one or more functions subject to equality or inequality constraints. The major fields of optimization are global, constrained, combinatorial, and multi-objective optimizations (Gen & Cheng, 2000).

- *Global optimization* is maximizing or minimizing a function in the absence of constraints.
- *Constrained optimization* deals with optimizing an objective function subject to equality or inequality constraints.
- *Combinatorial optimization* is used to determine either a permutation or a combination of some items associated with a problem or both. It could also be used to determine the above subject to some constraints.
- *Multi-objective optimization*, as the name suggests, deals with optimizing multiple objective functions simultaneously.

PROPOSED OPTIMIZATION MODEL

A subcarrier and power allocation problem could be classified as a combinatorial optimization problem. The objective

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