# Chapter XVI
# Transmission in MIMO OFDM Point to Multipoint Networks

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## ABSTRACT

*This chapter discusses four different optimization problems of practical importance for transmission in point to multipoint networks with a multiple input transmitter and multiple output receivers. Existing solutions to each of the problems are adapted to a multi-carrier transmission scheme by considering the special structure of the resulting space-frequency channels. Furthermore, for each of the problems, suboptimum approaches are presented that almost achieve optimum performance and, at the same time, do not have the iterative character of optimum algorithms, i.e., they deliver a solution in a fixed number of steps. The purpose of this chapter is to give an overview on optimum design of point to multipoint networks from an information theoretic perspective and to introduce non-iterative algorithms that are a good practical alternative to the sometimes costly iterative algorithms that achieve optimality.*

## INTRODUCTION

Increasing demand for broadband services calls for higher data rates in future communication systems. For instance, in fourth generation wireless communication systems data rates of several Mb/s in high mobility and 1 Gb/s in low mobility scenarios are expected (Tachikawa, 2003). Particularly challenging is the accomplishment of this goals in point to multipoint networks. In such networks, an access point transmits independent information to a number of users that compete for the available system resources, i.e., transmission time, transmit power, spectrum and space. Thus, the challenge consists in providing a satisfactory service to all users by making an adequate allocation of resources. Prominent examples of point to multipoint networks are the downlink of wireless local area networks, the downlink of mobile networks and the downstream direction of wired or wireless last mile access networks.

Spectral limitations, due to scarcity of spectrum in wireless systems and narrow bandwidths of customary copper wire in the last mile, together with the general frequency selectivity of wideband channels are two major barriers to be overcome in the way to data rates beyond those of current communication systems. Sending information over multiple inputs at the transmitter and retrieving information from multiple outputs at the receiver has the potential to increase the amount of information reliably transmitted per time and frequency unit, i.e., it allows a more efficient use of the spectrum (Foschini, 1998).[a] On the other hand, Orthogonal Frequency Division Multiplexing (OFDM) is able to transform the frequency selective channel into a set of non-interfering frequency flat channels, which enormously simplifies equalization at the receiver (Raleigh, 1998). Hence, combination of MIMO and OFDM seems to be key for implementation of future high rate communication systems (Sampath, 2002).

In this chapter we describe MIMO OFDM transmission schemes for point to multipoint networks that achieve optimum rates, that is, rate vectors at the boundary of the capacity region. Computation of optimum transmit parameters is performed by means of iterative algorithms involving a complexity that strongly depends on the a priori unknown number of iterations required to reach convergence. In addition, the optimum solution allocates interfering spatial dimensions to users, which makes it necessary to inform each user about the statistics of the interference that it receives. For each transmission scheme suboptimum allocation algorithms are presented that are able to closely approach performance of optimum approaches and exhibit two crucial advantages. Computation of optimum transmit parameters requires a complexity similar to that of only one iteration of the optimum approaches and users are assigned decoupled spatial dimensions, which makes possible the reduction of the required signaling overhead.

## System Model

We consider a typical multiuser MIMO OFDM system model where the signal $\mathbf{y}_{k,n} \in \mathrm{C}^{r_k \times 1}$ received by user $k \in \{1, 2, \ldots, K\}$ on subcarrier $n \in \{1, 2, \ldots, N\}$ is given by

$$\boldsymbol{y}_{k,n} = \boldsymbol{H}_{k,n}\boldsymbol{x}_n + \boldsymbol{n}_{k,n}, \tag{1}$$

where $\mathbf{H}_{k,n} \in \mathrm{C}^{r_k \times t}$ is a matrix modeling the channel between the transmitter and user $k$ on subcarrier $n$, $\mathbf{x}_n \in \mathrm{C}^{t \times 1}$ is the vector of transmit signals on subcarrier $n$ and $\mathbf{n}_{k,n} \in \mathrm{C}^{r_k \times 1}$ is a vector representing additive white Gaussian noise with covariance matrix $\mathrm{E}\{\boldsymbol{n}_{k,n}\boldsymbol{n}_{k,n}^{\mathrm{H}}\} = \boldsymbol{I}$, where $\mathrm{E}\{\bullet\}$ denotes the expectation operator. The variables $t$ and $r_k$ denote the number of transmit and receive antennas, respectively. Perfect channel knowledge is assumed at both the transmitter and the receivers. This is a valid assumption if the channel is invariant over time as, for instance, in wired networks. In these cases, enough time is available to learn the channel at both ends of the communication link by employing an adequate signaling scheme. Also in wireless networks there exist scenarios where this assumption can be considered reasonable. These are typically indoor scenarios such as offices or hotspots in airports or other public areas. In such scenarios mobility is low and long coherence times allow to learn the channel with a moderate signaling overhead. The transmit signal is formed by superposition of the signals intended for each of the users as

$$\boldsymbol{x}_n = \sum_{k=1}^{K} \boldsymbol{x}_{k,n}.$$

In terms of capacity, the optimum choice for the statistics of the transmit signals $\boldsymbol{x}_{k,n}$ is a zero mean Gaussian distribution (Weingarten, 2006). The covariance matrices $\boldsymbol{Q}_{k,n} = \mathrm{E}\{\boldsymbol{x}_{k,n}\boldsymbol{x}_{k,n}^{\mathrm{H}}\}$ are required to satisfy the following transmit power constraint

$$\sum_{n=1}^{N}\sum_{k=1}^{K} \mathrm{Trace}\{\boldsymbol{Q}_{k,n}\} \le P \tag{2}$$

In the sequel we introduce four of the most significant problem statements related to the optimization of transmit parameters in the broadcast channel. For each problem we first briefly describe the existing optimum solution before we introduce the corresponding suboptimum approach.

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