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# Optimal adaptive channel scheduling for scalable video broadcasting over MIMO wireless networks ☆

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ABSTRACT

Video broadcasting is an efficient way to deliver video content to multiple receivers. However, due to heterogeneous channel conditions in MIMO wireless networks, it is challenging for video broadcasting to map scalable video layers to proper MIMO transmit antennas to minimize the average overall video transmission distortion. In this paper, we investigate the channel scheduling problem for broadcasting scalable video content over MIMO wireless networks. An adaptive channel scheduling based unequal error protection (UEP) video broadcasting scheme is proposed. In the scheme, video layers are protected unequally by being mapped to appropriate antennas, and the average overall distortion of all receivers is minimized. We formulate this scheme into a non-linear combinatorial optimization problem. It is not practical to solve the problem by an exhaustive search method with heavy computational complexity. Instead, an efficient branch-and-bound based channel scheduling algorithm, named TBCS, is developed. TBCS finds the global optimal solution with much lower complexity. The complexity is further reduced by relaxing the termination condition of TBCS, which produces a $(1-\varepsilon)$-optimal solution. Experimental results demonstrate both the effectiveness and efficiency of our proposed scheme and algorithm. As compared with some existing channel scheduling methods, TBCS improves the quality of video broadcasting across all receivers significantly.



## 1. Introduction

The broadcast nature of wireless medium allows a single source to simultaneously communicate information with multiple receivers. However, one major challenge for wireless broadcasting arises from heterogeneous network conditions of different receivers. Moreover, the potentially low bandwidth and high bit error rate also become significant obstacles for wireless communication providers to offer high quality multimedia services. To overcome such obstacles, multi-input multi-output (MIMO) systems, which have been investigated to simultaneously transmit multiple bit streams to achieve high data rate wireless multimedia communication [1], have emerged as one of the most prominent techniques. MIMO channel can be decomposed into a series of independent SISO subchannels [2], and it is suitable for transmitting multiple video substreams simultaneously. Meanwhile, the technology of scalable video coding (SVC) [3,4] enables media providers to generate a single embedded bitstream, from which appropriate subsets can be extracted to meet various requirements of a broad range of users. These conditions inspire us to combine the advanced MIMO and SVC techniques to improve the video broadcasting performance. SVC video consists of layers with different contribution to video quality, which makes it possible be transmitted with unequal error protection (UEP) [5–7]. In MIMO unicast, UEP can be easily achieved by mapping



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video layers to antennas in the order of antenna's signal to noise ratio (SNR) strength [6]. However, it is not trivial for video broadcasting over MIMO wireless networks, and this has not drawn enough research attention.

Adaptive channel scheduling, which denotes mapping video layers to proper antennas to improve video transmission performance, faces great challenges for scalable video broadcasting over MIMO wireless networks. It mainly arises from that each transmit antenna corresponds to multiple receivers with different and independent SNR strength, and the corresponding SNR strength for each transmit antenna among multiple receivers forms a vector. For example, in Fig. 1, antenna $A_{t1}$ is corresponding to three receivers ($A_{t1} - User1$, $A_{t1} - User2$, $A_{t1} - User3$), whose SNR strength form the vector $\Upsilon_1 = [\gamma_{11}, \gamma_{12}, \gamma_{13}]$. It is the same for antenna $A_{t2}$. since sets of vectors cannot be sorted, UEP cannot be achieved by mapping video layers to antennas in the order of antenna's SNR strength as done in MIMO unicast. Besides, the inter-layer dependencies among SVC video layers further make the problem challenging.

In this paper, we have studied this problem and proposed a novel adaptive channel scheduling based scalable video broadcasting scheme, which greatly improve the received video quality. By mapping each video layer to certain transmit antenna, the video layers are protected unequally and the overall average video quality is improved. Since each antenna faces multiple users with various network conditions as Fig. 1 shows, and there exists inter-layer dependencies among SVC video layers, the channel scheduling problem is a non-linear combinatorial problem. It can be solved using an exhaustive search method, which has the highest accuracy level and computational complexity. In order to reduce the complexity and make it suitable for practical implementation, a branch-and-bound framework is adopted to find an adaptive channel scheduling algorithm. Specifically, by partitioning the original problem into some simple sub-problems, we are able to derive the upper and lower bounds of the average overall video distortion. Then an efficient branch-and-bound based channel scheduling algorithm (TBCS) is presented by incorporating these bounds into the branch-and-bound framework. With bounding and pruning techniques, TBCS finds the global optimal solution with much lower complexity than the exhaustive search method. Moreover, by relaxing termination conditions of TBCS, the complexity is further reduced and a $(1-\varepsilon)$-optimal solution is produced. Through simulations, TBCS is shown to be effective and efficient. As compared with existing channel scheduling schemes, the simulation results reveal significant performance improvements in TBCS.

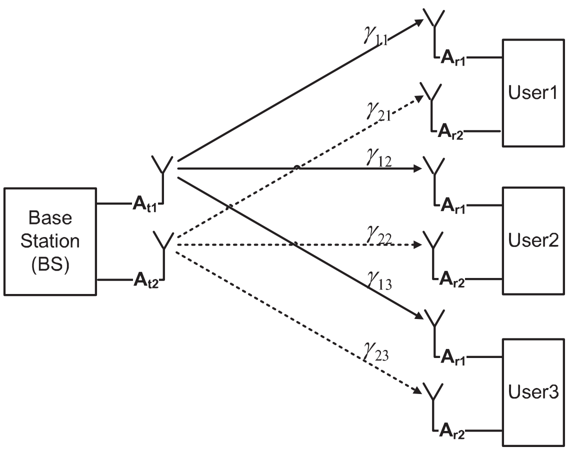


**Fig. 1.** Example of video broadcasting in MIMO wireless networks.

The main contributions of our work are summarized as:

- We are among the first to investigate the channel scheduling problem for salable video broadcasting over MIMO wireless networks where video layers are broadcasted to all users simultaneously over multiple antennas. Different from traditional multiuser problem over MIMO broadcast channel where different information is conveyed to different users by multiple transmit antennas, the antennas are shared by all users who receive all streams broadcasted over the antennas in our proposed scheme.
- We formulate it into a non-linear combinatorial optimization problem, and an efficient channel scheduling algorithm is proposed by employing the branch-and-bound framework. Specifically, by mapping the video layers to antennas according to the order of antennas' average PER, we derive the upper bound of the average overall video transmission distortion. On the other hand, we transform the channel scheduling problem to an assignment problem by relaxing some constraints, and then the lower bound of the average overall video transmission distortion is derived.
- By relaxing the termination condition of TBCS, a $(1-\varepsilon)$-optimal solution is produced to balance the needs for the complexity and accuracy of the proposed algorithm.

This paper is organized as follows. We review related work in Section 2. In Section 3, we describe our proposed system and formulate the proposed scheme into a non-linear combinatorial optimization problem. In Section 4, we propose a branch-and-bound framework to solve the channel scheduling problem. First, we derive the upper bound (Section 4.2) and and lower bound (Section 4.3) of the average overall distortion respectively, then an efficient branch-and-bound based channel scheduling algorithm is proposed, which produces the global optimal solution (Section 4.4). Also, an acceleration mechanism is presented to further reduce the computational complexity (Section 4.5). We show simulation results in Section 5, and conclude the paper in Section 6.

## 2. Related work

In recent years, MIMO systems have emerged as one of the most prominent techniques [1,8–10] to provide high data rate wireless communications. Spatial multiplexing techniques [1,10] have been investigated to simultaneously transmit independent data in order to achieve high data rate wireless multimedia communications. For MIMO broadcast, the capacity region is still an open issue since broadcast channels are non-degraded generally. But the