

# COOPMEDIA: Cooperative Multimedia Transmission over Wireless Networks

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## Project Objectives

Multimedia transmission over mobile devices is one of the most prominent emerging applications in mobile communications. With the rapid proliferation of 3G systems worldwide, multimedia services has become a regular part of our daily mobile communications experience. Mobile video traffic exceeded 50 percent of the total mobile data traffic for the first time in 2011. This ratio is expected to surpass 70 percent by 2016. Wireless networks are critically sensitive to the load in the network, and the users' quality of experience (QoE) is under a risk of significant decline with this growth. Network providers are already having problems supporting this growth within the current network architecture. To avoid a potential network meltdown, one approach is to increase the capacity of the wireless networks. However, simply increasing the network capacity, without taking into account the specific characteristics of the underlying multimedia signals will simply postpone the catastrophe. A more fundamental approach is to go beyond the layered network architecture, and study the underlying problem from a joint source-channel coding (JSCC) perspective.

The objective of COOPMEDIA is to advance our understanding on the fundamentals of cooperative multimedia transmission over wireless networks by defining the appropriate performance measures for different applications and developing the tools to improve the system performance with respect to these performance measures. In particular, COOPMEDIA focuses on the information and communication theoretical aspects of multimedia transmission, and strives to identify the fundamental limits of joint source-channel coding in networks while taking practical constraints and performance metrics into account.

## Main Project Results

- **Joint Source-Channel Coding with Fading Side Information:** We have studied transmission of a Gaussian source over a multiple input-multiple output (MIMO) fading channel with time-varying correlated side information at the decoder. This can model the transmission of a video signal over a wireless fading channel when the receiver has access to a correlated video signal, which might be the video recording of the same scene from a different angle. Focusing on the high SNR behavior of the end-to-end distortion, we have identified the optimal transmission scheme.

We have then extended our study to the moderate SNR levels which would model more practical modes of operation. As a surprising result, we have shown that for

single input-single output (SISO) systems in the case of bandwidth match, that is, when the source and the channel bandwidths are the same, uncoded transmission achieves exactly the optimal performance. Our high SNR analysis has shown that uncoded transmission is exponentially worse than coded schemes when there are multiple antennas or bandwidth expansion/ compression. This points to an interesting result which implies that for simple SISO systems coding might not be needed, simplifying the operation of the devices significantly. Such results were previously obtained for some special multiple access scenarios, but this is the first such result in the case of fading channel and side information.

- **Joint Source-Channel Cooperative Transmission over Networks** We have focused on lossless transmission of correlated sources over various multi-user networks. In particular, we have focused on relay-broadcast networks and multiple access relay channel (MARC).

In the case of relay-broadcast networks, we have identified two types of transmission strategies: i) semi-regular encoding with backward decoding, and ii) regular encoding with sliding-window decoding. We have shown that these coding schemes achieve the optimal source-channel coding rate for physically degraded relay channel with degraded side information and the relay broadcast channel with arbitrary side information.

In MARCs, we have considered separate source channel coding as well as correlation preserving mapping, and showed that either transmission scheme can be superior depending on the sources and the channels.

- **Streaming of Multimedia Signals** We have studied multimedia streaming applications in which data packets arrive at the transmitter over time and has to be broadcast to a group of receivers within a certain deadline over fading channels. Assuming that the transmitter is oblivious to the underlying source encoder, we have studied transmission schemes in which the transmitter is allowed to choose which packets to forward to the destination, and how to allocate time and power among these packets. We have studied the average throughput as well as the maximum delay among consecutive decoded packets, the two most important quality of user experience in streaming applications.
- **Energy Efficient Multimedia Transmission** Energy efficiency is a fundamental concern in almost all communication systems, but especially for mobile networks which are limited by the stored energy in the battery. In this project, we have introduced the novel concept of *energy-distortion trade-off* which measures the fundamental limit of energy efficiency in transmitting sources over wireless channels when the bandwidth ratio between the channel and the source is relaxed. Moreover, we have also studied energy harvesting communication systems, which are not limited by the stored energy, but can harvest ambient energy to sustain transmission over longer periods of time than allowed by the battery capacity.