This dissertation is concerned with the design of time scheduling and signal processing algorithms to mitigate interference effects in wireless networks with successive relaying where the nodes in the system are equipped with multiple antennas. These networks as a form of cooperative communications and multiple-input multiple-output (MIMO) systems have the promise of significantly higher spectral efficiency and reliability than the conventional networks. Reusing the same spectrum by simultaneous multiple transmissions in successive relaying increases spectrum efficiency however it also causes interference which if not mitigated may limit the overall wireless network performance. With these motivations, this dissertation presents three main contributions to lessen or completely cancel relay interference and improve bandwidth efficiency.

First, we consider relay-assisted downlink transmissions to support increased data rates for single antenna users. In the first stage of the communication process, the base station with multiple antennas sends to different users. In the next stage, users and their assigned relays form independent networks. Relays using an amplify-and-forward (AF) scheme aid the recovery of messages by solving linear system of equations developed in this dissertation. All of these subnetworks utilize the same bandwidth concurrently producing an acceptable level of multiple access interference (MAI) where the MAI is controlled using specialized frequency reuse plan.

Secondly, we develop receiver-based inter-relay interference (IRI) cancellation in AF two-hop systems with successive transmissions. In networks with strong inter-relay channel gains, representing IRI with the recursive terms and exploiting opportunistic listening, in this dissertation, this interference is fully removed using limited channel state information (CSI) about channel gain matrices from both hops.

Finally, to complement our second contribution, we develop transmitter precoding to cancel IRI in systems with successive relaying. When designing the scheme, we benefit from the broadcast channel characteristic of the radio channel and the knowledge at the source of all the data contributing to IRI. This dissertation advances the theory of successive relaying through its integration with time scheduling and signal processing within the framework of cooperative communications system designs. The results presented in this work are applicable to wireless networks on downlink and uplink in systems ranging from cellular to ad-hoc networks.