Relaying for Interference Management

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The design of future communication systems is focused on the joint performance enhancement of concurrently active nodes within wireless networks. Such networks suffer from several limitations such as interference and bad connectivity. Relaying is an effective method to overcome such limitations. Namely, relay nodes can be used for managing interference in a wireless network in a controlled way so that the impact of this interference is reduced, and for providing alternate connectivity paths in networks with connectivity problems. The goal of this thesis is to study optimal strategies for exploiting the relay benefits in a wireless network and quantifying the resulting performance improvement.

The two user interference channel is an elemental network which captures the aforementioned limitations, and can be used as a stepping stone towards understanding larger networks. By installing a relay node which listens to the sources and relays information to the destinations in an interference channel, we obtain the so-called interference relay channel. The capacity of this network, which is defined as the maximum rate for reliable communication, is in general unknown. This is due to the fact that the capacity characterization of interference networks is non-trivial and, for more than three decades, an open problem. This thesis achieves progress on this front as follows. We resort to an approximative characterization of the sum-capacity (the total achievable rate) which focuses on the high signal-to-noise ratio regime (the interference-limited regime). New sum-capacity upper bounds for the network are derived using both novel and classical methods. To judge the tightness of these upper bounds, they are tested against new sum-capacity lower bounds obtained by using a novel relaying strategy. This new strategy is based on computation at the relay; that is, the relay decodes a linear combination (a network code) of the transmit signals of the two users. The relay signal is then used afterwards for interference management at the destinations, which in turn, after some processing, are able to perform interference cancellation. It turns out that the proposed strategy does not only outperform classical relaying strategies for the interference relay channel, but also provides an asymptotically exact characterization of the sum-capacity of the network for a wide range of channel parameters. Interestingly, the results show that the relay can increase the capacity of the network even if the relay has very weak reception. In order to emphasize the impact of relaying, we also explore another form of relaying in which the relay node does not only relay information to the destinations (forward-relaying) but also to the sources (backward-relaying). The impact of backward-relaying, which can also be interpreted as relay- source feedback, on the capacity of the interference relay channel is analyzed and it is shown that this this backward signaling provides a sum-capacity gain of 2 bits per feedback bit.