

## Chapter 5

# Spectral Efficient Opportunistic Relay Selection Policies for Next Generation Mobile Systems

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### ABSTRACT

*This book chapter presents various relay selection policies based on spectral efficient techniques for the next generation mobile systems. Successive opportunistic relaying (SOR) that leverages the half-duplex constraint of conventional relays through concurrent transmissions is described, while proposing techniques to reduce the effect of inter-relay interference (IRI). An extension of SOR is defined for the case of out-of-band relaying, when additional spectrum bands are available and in networks with buffer-aided relays. Moreover, the use of full-duplex (FD) relays is outlined, in view of the effect of loop-interference (LI) from the relay's output to its input and, also, the power reduction is presented. As networks with multiple relays suffer from increased coordination overhead, a reduced Channel State Information (CSI) policy is proposed. For every policy, performance evaluation is provided in terms of outage probability, average throughput, power reduction and switching rate. Finally, open problems in spectral-efficient opportunistic relay selection policies are discussed.*

### INTRODUCTION

In recent years, wireless networks have seen a tremendous increase in terms of the achieved Quality of Service (QoS). Cooperative techniques have significantly contributed towards improving the capacity of the fourth generation 4G and beyond networks and are considered a basic element of

the imminent 5G networks. Among cooperative techniques, cooperative relaying has received significant attention from researchers due to the gains it offers to the network. More specifically, relay transmissions reduce the pathloss, as the transmitter is located closer to the receiver, compared to traditional single-hop transmissions. Also, the use of more than one relays allow the

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formation of distributed antenna arrays that increase the diversity of the network, as the signal propagates through independent paths (Laneman, Tse, & Wornell, 2004). In addition, shadowing can be mitigated through optimal positioning of relays in order to avoid blockages from obstacles and clutter.

Regarding the relay transmissions, a technique that has received a large amount of contributions is the opportunistic relay selection. Opportunistic Relay (OR) selection has been proved to achieve the same diversity order as multiple relay transmissions, while requiring only one orthogonal resource in time or frequency (Bletsas et al., 2006). This additional resource is needed due to the half-duplex relay operation, which dictates that a relay cannot transmit and receive simultaneously. Recently, several selection policies using relays with buffering capabilities have been presented and so, the constraint of using the same relay for reception and transmission in the next time-slot has been broken. An additional degree of freedom has been given to relay selection through the adaptive link selection that activated the best link among the source-relay (SR) and relay-destination (RD) links (Krikidis, Charalambous, & Thompson, 2012a).

The purpose of this book chapter is to present a family of spectral efficient OR selection policies. First, we provide the state-of-the art of conventional cooperative relaying and we outline its shortcomings. One major drawback of conventional relaying protocols is that a transmission spans in two time-slots and thus the end-to-end rate is halved. Thus, to leverage the half-duplex constraint, spectral-efficient protocols, such as successive relaying, have been investigated and a corresponding survey is provided. As multiple relays can be considered to facilitate the communication between a source and a destination, OR selection can enhance significantly the spectral efficiency of the network and this is evident through the relevant works that we discuss.

The first policy employs the Successive Opportunistic Relaying (SOR) technique that allows

two transmissions to be performed concurrently in networks with at least two available relays. As one relay forwards a previous packet to the destination, while the source transmits a new packet to another relay with the exception of the first time-slot, the destination receives one packet in each slot and, in the long-term, full-duplex operation is achieved. However, this overlap of transmissions introduces IRI that must be mitigated. In continuity we present SOR for networks with buffer-aided relays that offer additional degrees of freedom in IRI mitigation.

As 5G techniques are starting to be developed, the use of additional spectrum bands and multiple interface (or multi-mode) terminals are considered as measures to avoid interference in relay transmissions. So, we will include in the chapter an extension to SOR with multi-mode relays that are Long Term Evolution (LTE) and Wi-Fi capable and switch interfaces in order to nullify interference. In this particular relay selection policy, power adaptive transmissions lead to power reduction, as well as IRI mitigation, due to the lower level of interference from the transmitting relay.

Following, we provide details on the hybrid combination of single-link selection and SOR, thus forming a selection policy that offers robustness and spectral efficiency. Furthermore, an analysis on power minimization through power adaptive transmissions will also be given. Subsequently, we discuss another way to increase spectral efficiency through the use of full-duplex relays that are able to transmit and receive at the same time, as long as the degrading effect of LI is tackled. Therefore, a second hybrid selection policy that combines single-link selection, SOR and FD relaying is described while, at the same time, power adaptation provides IRI and LI mitigation and power reduction.

It is obvious that in networks with multiple available relays, the tasks of coordination and relay selection require significant amounts of overhead that may render the practical implementation of relay selection infeasible. To reduce CSI acquisi-

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