

Title: L2 Relay Interference Mitigation
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1. Introduction

In LTE-A, relay technologies have been included to improve average system throughput and cell edge coverage [1- 8]. In this contribution we focus on the L2 relay in an FDD system and suggest basic transmission and reception schemes and resource allocation schemes that may reduce interference from UEs positioned in RN donor cells communicating on access links and UEs positioned in the cell and communicating on direct links.

2. Simple Time Division Based Transmission and Reception

In a cell with RNs, there are three different types of radio links: a *direct link* between the UE and eNB, a *relay link* between the relay and eNB and an *access link* between the UE and relay. One issue for the Relay Node (RN) is how to transmit and/or receive on a given relay link, and access link on the same LTE-A band (in-band relay) while maintaining simplicity. Another related issue is how to reduce the possible interference due to UEs near the RN but communicating with the cell's eNB. Note that the RN schedules the UE resources over the access link not the eNB.

2.1. RNs operate in Time-Division Mode

It is technically challenging to build an RN that can transmit and receive on the same carrier simultaneously. Hence a system should be architected such that the RN does not have to transmit to the eNB and receive from a UE on the same TTI and on the same carrier frequency. This means that time division for transmissions and receptions are necessary. Following are two examples of how one would do this.

Figure 1 shows a half-duplex, dual-radio scheme. It shows where the TTIs are separated into two distinct times, T1 and T2 (for example, by alternating). Here we only consider the data region of a subframe (PDSCH/PUSCH), not the control region such as PDCCH/PHICH/PUCCH/SRS/etc. In T1, the RN receives the data from the eNB and the UE, and in T2 the RN transmits the data to the eNB and the UE. We call this Mode 1.

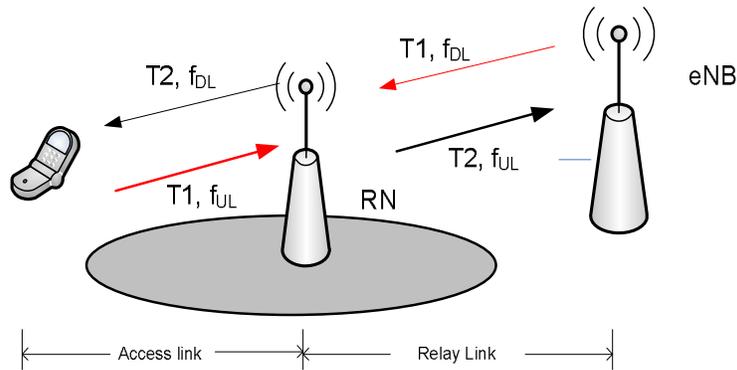


Figure 1. Mode 1 transmission/reception for RNs. T1 transmissions are represented with red arrows, and T2 transmission are represented with black arrows.

Figure 2 shows a full-duplex transmission at alternating times. It shows where communication occurs with the eNB and UE at two separate TTIs, T1 and T2 (for example, by alternating). Again, we only consider the data region of a subframe (PDSCH/PUSCH), not the control region such as PDCCH/PHICH/PUCCH/SRS/etc. In T1, the RN transmits/receives the data to/from the eNB only. In T2, the RN transmits/receives the data to/from the camped UE only. We call this Mode 2.

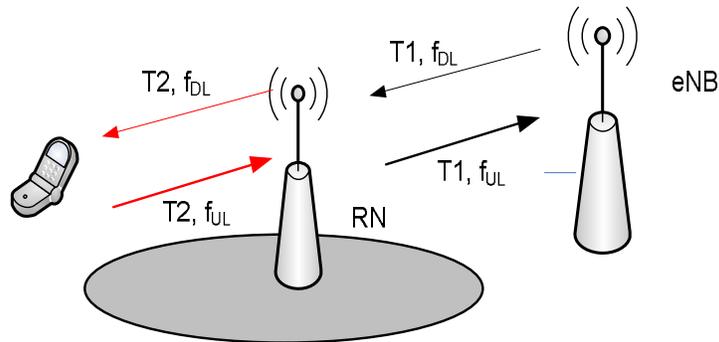


Figure 2. Mode 2 transmission/reception for RNs

For simplicity, when multiple two-hop RN architectures are configured, we suggest that T1 and T2 for all RNs be the same. This also helps reduce the interference that may arise due to the independent scheduling among the eNB and RNs. The actual pattern of T1 and T2 could be based on the HARQ feedback timing/resource, RN/eNB loading, and other aspects such as imbalanced link performance between the relay link and access link. A simple example could be that T1 and T2 alternate every TTI.

2.2. Interference Considerations and Frequency Resource Allocation

The incurred interference due to the addition of RNs to an LTE-A system should be considered carefully. Both Mode 1 and Mode 2 are considered in the following.

2.2.1. Resource Allocation for Mode 1

Figure 3 shows an example of the time divisions and carrier frequencies necessary for a UE in a RN donor cell and a UE outside of the RN donor cell. The UE outside the RN donor cell communicates in FDD on the direct link. It is easy to see that during TTI T1, there is the possibility of interference at the RN (and eNB) between the UL transmission of the UE in the donor cell and the UE outside the donor cell. The possibility arises due to the independence of the scheduling at the eNB and RN.

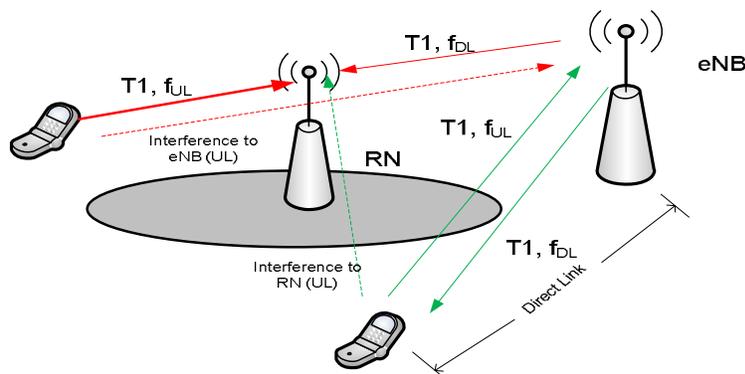


Figure 3. UL interference scenario for mode 1 during TTI T1.

If the RN assigns the same RBs for the UE to be transmitted over the access link as the eNB assigns to the UE to be transmitted over the direct link, then the RN reception will suffer at least minor interference from the uplink transmission on the direct link. Further, the eNB reception will suffer similar interference from the uplink transmission on the access link. If the eNB schedules the RN as if it is another UE, then both the RN reception and the UE reception will be interference free.

Similarly, Figure 4 shows a typical interference scenario for TTI T2. Interference may occur when the RN transmits on the same RBs to the UE over the access link as the eNB transmits to the UE over the direct link. As before, if the eNB schedules the RN like it is any other UE, then the UL transmission will be interference free.

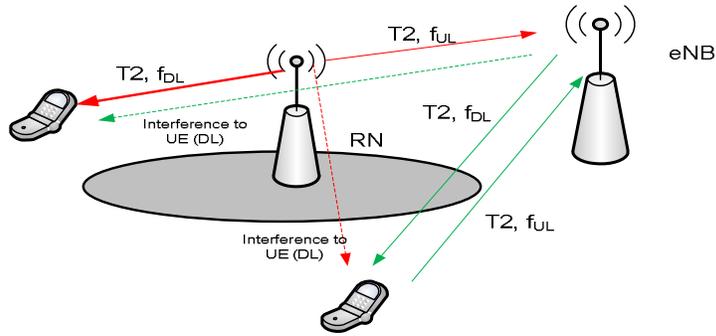


Figure 4. DL interference scenario for mode 1 during TTI T2

Interference described above should be avoided as much as possible in an attempt to keep system capacities as high as possible. It may be then necessary to coordinate the otherwise independent scheduling at the eNB and RN.

We begin by noting that in Mode 1 during TTI T1 all downlink transmission are coming from the eNB and, therefore, there is no interference from UEs within the cell. We also note that in Mode1 during TTI T2, all UL transmissions are scheduled by the eNB, eliminating interference from inside the cell. We suggest the following scheduling coordination for UL transmissions in T1 and DL transmissions in T2:

1. The eNB allocate/reallocate frequency resources for each RN in both the uplink and the downlink;
2. RNs should only use the allocated resources for their independent scheduling; and
3. The resource allocation could be either a
 - a. Fixed allocation (the resource is permanently allocated), or a
 - b. Semi-static allocation based on loading situations.

An eNB can allocate the same resource to all RNs when the RNs are located far away from each other physically. Certain resources may be reserved for real-time interactive services such as VoIP.

In Figure 5, an example is shown during T1. For the DL, the eNB schedules all transmissions to the RNs and the UEs with direct link. We call this Full Resource Scheduling (FRS). For the UL, RNs only use allocated uplink frequency resources to schedule the uplink transmission on the access link. The allocations could be, for example, continuous groups of uplink RBs. The eNB uses the remaining uplink resources (in our example, available RBs) to schedule the UL transmissions from the UEs that communicates over the direct link. We call this Partial Resource Scheduling (PRS). It should be noted that the allocated resources in the PRS can be re-used in different RNs based on their location.

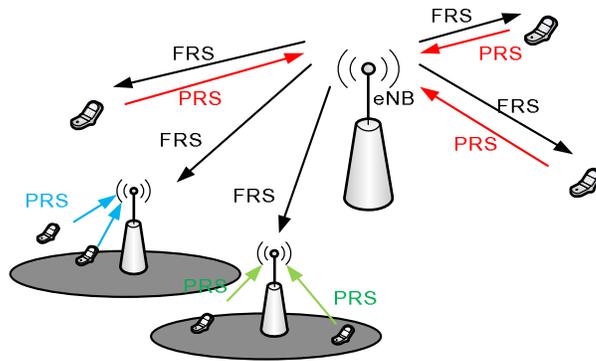


Figure 5. T1 transmission/receptions and interference avoidance for Mode 1

In Figure 6, an example is shown during T2. FRS is applied on the UL to schedule the transmissions from the RNs and the UEs with direct link. PRS is applied on the DL to the RNs and the eNB to schedule the downlink transmissions on the access link.

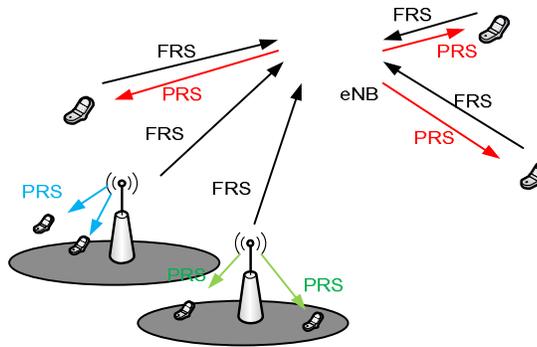


Figure 6. T2 transmission/reception and interference avoidance for Mode 1

2.2.2. Resource Allocation for Mode 2

Now we will do an abbreviated but similar analysis for Mode 2. During T1, the RN has an FDD communication with the eNB on the relay link while the UE could have an FDD communication on the direct link. There will be no interference since the eNB can schedule both links.

Conversely during T2, the UE in the donor cell has an FDD communication with the RN. A UE communicating on the direct link with the eNB would suffer at least some interference on both the UL and DL. Hence, as is shown in Figure 7, FRS should be used on the relay link and PRS should be used on the access link.

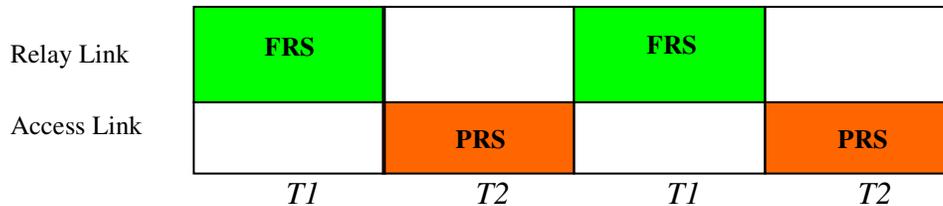


Figure 7. Mode 2 interference avoidance by applying the PRS and FRS

3. Summary

In this paper, we discussed means for mitigating interference when adding L2 relays to an FDD system and propose that LTE-A:

1. Apply simple time division based transmission and reception scheme for L2 relays, either Mode 1 or Mode 2.
2. Have the eNB allocate (fixed or semi-statically) PDSCH/PUSCH resources for the RNs to avoid interference that might be caused by the independent scheduling between the eNB and the RNs.

References

- [1] R1-083533, "Decode and Forward Relays for E-UTRA enhancements", TI
- [2] R1-083676, "Discussion on the TD relay and FD relay for FDD system", Panasonic
- [3] R1-082024, "Discussion on some technology components for LTE-Advanced", Ericsson
- [4] R1-082975, "Application Scenarios for LTE-Advanced Relay", China Mobile, Vodafone, Huawei
- [5] R1-082327, "Application of network coding in LTE-advanced relay", Samsung
- [6] R1-083191, "Operation of relays in LTE-A", Qualcomm
- [7] R1-083223, "Classification of Relays", Motorola
- [8] R1-082775, "Basic structure of relaying under multi-antenna eNB", Mitsubishi Electric