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Title: Type 1 Relay Performance Characterization: Dependency with Channel Model Assumptions

Document for: Discussion and Decision

1 Introduction

The subject of channel modeling for relay deployments has been discussed extensively in the past few RAN1 meetings, and these discussions have resulted in several revisions to the access, backhaul and direct link channel models used for relay deployments. This contribution is an update of [1] in which relay performance is evaluated using different channel model assumptions, and it is seen that system performance in the presence of relays is quite sensitive to the channel models used.

The following channel models are evaluated in this contribution:

- *All NLOS model*: In this model all links are assumed to be NLOS [2].
- *Mixed LOS/NLOS model with zero LOS probability for the direct link*: This model was agreed during RAN1#57bis [3], in which the backhaul link and access link both have distance dependent LOS probability. The LOS probability of the direct link is set to zero in this case.
- *All mixed LOS/NLOS model*: This is the model in [3], plus an additional distance dependent LOS probability for the directl link as proposed in [4].
- *Separation of LOS and NLOS terms*: This is the channel model in the current evaluation methodology [5], in which the LOS and NLOS terms have been separated in the path loss formula for all links. There is a LOS probability on all links.

Two relaying schemes are simulated, namely the L3 Relay and Advanced L3 Relay described in [6]. L3 relays act like a regular cell with wireless inband backhaul. The cell selection algorithm is based on highest DL received power among all macro cells and relay cells. Advanced L3 relays deploy range expansion cell-selection algorithms and cooperative silencing schemes. The simulation results in this contribution assume a simplistic cooperative silencing scheme where the macro cells remain silent for a number of subframes during each radio frame. These subframes are used for relay to UE transmissions. Since dominant interference from macro cells to UEs served by relays are effectively mitigated, a range expansion cell-selection algorithm can be used to increase the effectiveness of relay deployment.

In both L3 Relay and Advanced L3 Relay designs, we consider a two-hop design where a UE is allowed to connect to a donor cell via relay with one access link hop (UE <=> relay) and one backhaul hop (relay <=> eNB).

2 Numerical Results

Tables 1 and 2 below show the tail and median UE throughput in relay deployments using the different channel models mentioned in the previous section, while Figures 1 and 2 illustrate the results. Both, tables and figures show the increase in throughput obtained by deploying relays in a macro-only deployment.

The basic L3 relay simulation results shown here assume that the relay node can transmit data in any subframe in which it is not scheduled on the backhaul. This is a somewhat optimistic assumption since in practice the access-backhaul partitioning for any given relay will have to be determined in a semi-static manner.

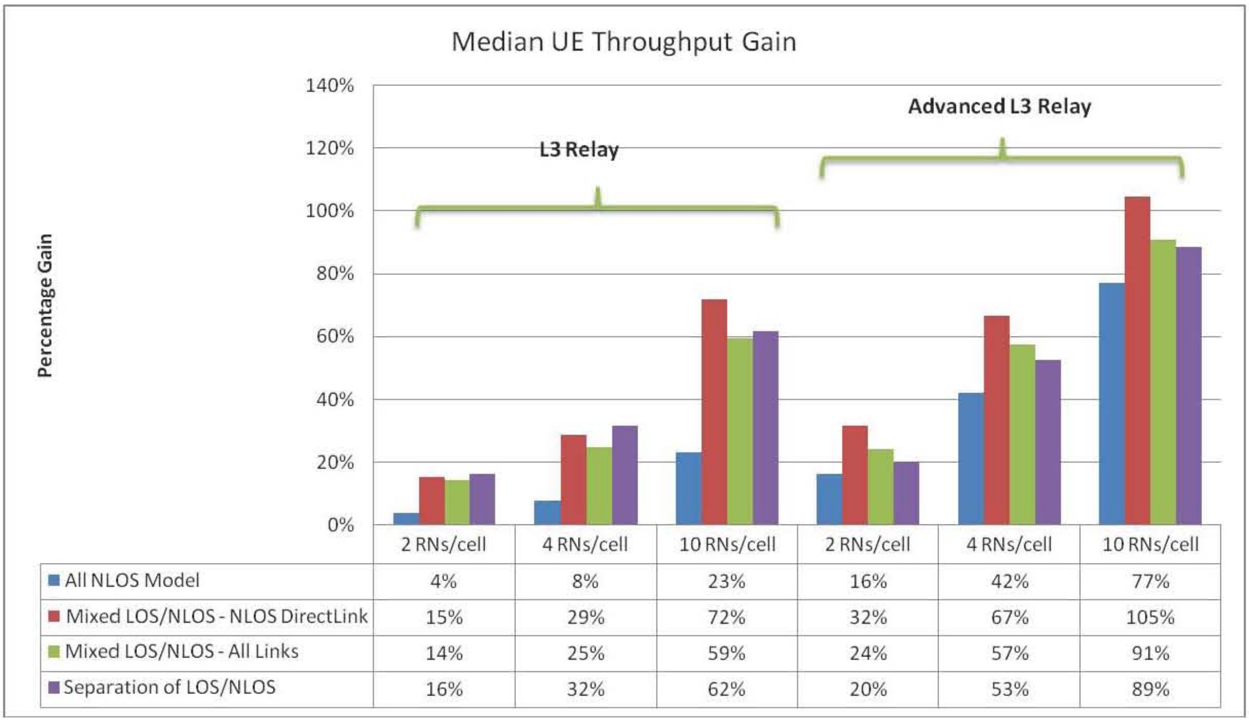
The advanced L3 relay simulation results use subframe partitioning between resources allocated to access and backhaul links. In particular, some of the subframes are used by relay nodes to serve relay UEs, while the remaining subframes are used by the macro to serve both relays as well as macro UEs. The macro cells do not transmit in subframes used by relays to serve relay UEs. This partitioning ensures that relay UEs do not see interference from high-powered macro signals. On the other hand, some relay UEs are located quite close to the relay and could be scheduled even in the presence of macro transmissions (this is particularly true once an LOS probability is introduced on the access link); further improvements in advanced d L3 relay performance could be obtained by taking advantage of this property.

Table 1 Throuput per UE in kbps for two different channel models. Numbers in Parentheses represent gain w.r.t. macro-only deployment

		ALL NLOS		MIXED LOS/NLOS ON ACCESS/BACKHAUL LINKS; NLOS ONLY ON DIRECT LINK	
		5% Tail	**Median**	**5% Tail**	**Median**
Macro Only		254	347	254	347
L3 Relays	**2 RNs**	257 (1%)	360 (4%)	275 (8%)	400 (15%)
	4 RNs	280 (10%)	374 (8%)	323 (27%)	446 (29%)
	10 RNs	305 (20%)	427 (23%)	422 (66%)	596 (72%)
Advanced L3 Relays	**2 RNs**	279 (10%)	403 (16%)	290 (14%)	457 (32%)
	4 RNs	318 (25%)	493 (42%)	347 (37%)	578 (67%)
	10 RNs	428 (69%)	614 (77%)	459 (81%)	710 (105%)

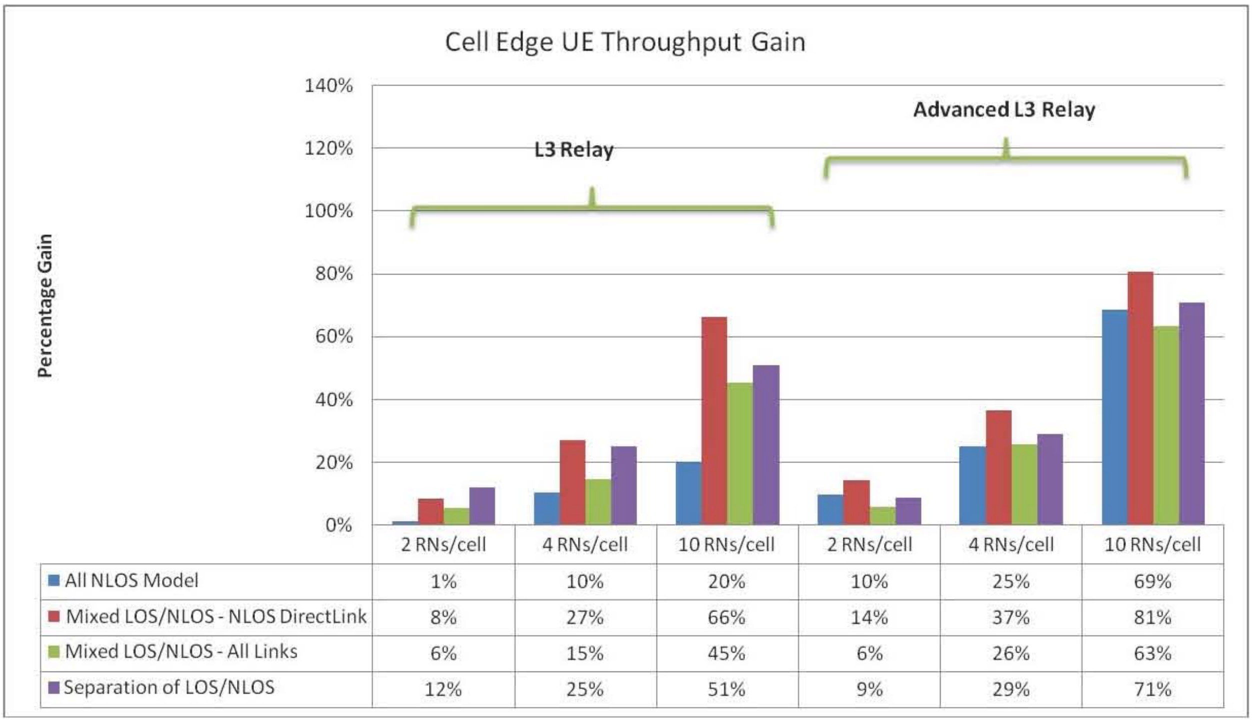
Table 2 Throuput per UE in kbps for two different channel models. Numbers in Parentheses represent gain w.r.t. macro-only deployment

		MIXED LOS/NLOS ON ALL LINKS		SEPARATION OF LOS/NLOS TERMS; LOS MODELING ON ALL LINKS	
		5% Tail	**Median**	**5% Tail**	**Median**
Macro Only		288	378	299	409
L3 Relays	**2 RNs**	304 (6%)	432 (14%)	335 (12%)	475 (16%)
	4 RNs	330 (15%)	471 (25%)	374 (25%)	538 (32%)
	10 RNs	419 (45%)	602 (59%)	451 (51%)	661 (62%)
Advanced L3 Relays	**2 RNs**	305 (6%)	469 (24%)	325 (9%)	491 (20%)
	4 RNs	362 (26%)	595 (57%)	386 (29%)	624 (53%)
	10 RNs	470 (63%)	721 (91%)	511 (71%)	771 (89%)



	2 RNs/cell	4 RNs/cell	10 RNs/cell	2 RNs/cell	4 RNs/cell	10 RNs/cell
All NLOS Model	4%	8%	23%	16%	42%	77%
Mixed LOS/NLOS - NLOS DirectLink	15%	29%	72%	32%	67%	105%
Mixed LOS/NLOS - All Links	14%	25%	59%	24%	57%	91%
Separation of LOS/NLOS	16%	32%	62%	20%	53%	89%

Figure 1. Per UE median throughput gain wrt the macro-only baseline.



	2 RNs/cell	4 RNs/cell	10 RNs/cell	2 RNs/cell	4 RNs/cell	10 RNs/cell
All NLOS Model	1%	10%	20%	10%	25%	69%
Mixed LOS/NLOS - NLOS DirectLink	8%	27%	66%	14%	37%	81%
Mixed LOS/NLOS - All Links	6%	15%	45%	6%	26%	63%
Separation of LOS/NLOS	12%	25%	51%	9%	29%	71%

Figure 2. Per UE cell edge throughput gain wrt the macro-only baseline.

We can make the following observations from the above results:

1) Introduction of an LOS component leads to a significant throughput increase in both macro-only deployments as well as relay deployments. Further, the gain due to deployment of relay also increases substantially once LOS modeling is included (even if LOS modeling is also used on the direct link). For example, for basic L3 relays and 10 relays/cell, the median UE throughput gain w.r.t. the macro-only case increases from 23% in the NLOS model to 59-72% with different forms of LOS modeling. Similarly, for advanced L3 relays, the throughput

gain with 10 relays/cell increases from 77% in the NLOS model to 89-105% with different forms of LOS modeling. The reason for the increase in performance from relay deployment is twofold:

a. LOS modeling on the backhaul link plus the additional gain due to site planning results in very high backhaul SNR, thus reducing backhaul constraints, and

b. LOS modeling on the access link results in expansion of the relay coverage area allowing the relay to serve more UEs with better SNR.

2) Introducing LOS probability in the direct link has an impact on macro-only deployment. The impact on system performance in the presence of relays is however not significant, especially for the case of high relay densities. Because of the improvement in the baseline, however, introducing LOS probability in the direct link slightly reduces the performance gain of relay deployments w.r.t. the macro-only baseline.

3) Separating the LOS and NLOS terms causes an increase in tail and median UE throughputs in both basic L3 relay and advanced L3 relay cases due to a larger fraction of UEs that have LOS connection to relay nodes.

4) Advanced L3 relays provide significant gain with respect to basic L3 relays in all the channel models considered. In fact, in all the situations considered so far, advanced L3 relays with 4 relays/cell show at least comparable median UE throughput as compared to basic L3 relays with 10 relays/cell. Further, because of the range expansion feature, advanced L3 relays provide significant throughput gains even in NLOS scenarios where the throughput gains from basic L3 relays are minimal. Further discussion on the performance advantages of advanced L3 relays can be found in [7].

5) Overall, we see that performance in relay deployments is much more sensitive to channel modeling assumptions than is seen in the macro-only case.

4 Summary

In this contribution we investigated the system performance impact of relay channel modelling. It was found that the relay performance is quite sensitive to LOS and NLOS modelling in the channel model, with different forms of LOS modeling providing a significant throughput increase as compared to the NLOS case.

Therefore, it is important not to limit relay evaluations to a single set of channel model assumptions for backhaul, access and direct links. Instead, we suggest assessing the performance advantages of relays for a range of channel models with different LOS/NLOS probabilities.

Finally, we have shown in this contribution that advanced L3 relays provide substantial performance benefits as compared to basic L3 relays in all cases. In fact, it was seen that in all cases, advanced L3 relays with 4 relays/cell show at least comparable median UE throughput as compared to basic L3 relays with 10 relays/cell.

References

[1] R1-093116, “Type 1 relay performance characterization: dependency with channel model assumptions,” Qualcomm Europe.
[2] 3GPP TR 36.814 v1.0.0 “Further Advancements for E-UTRA: Physical Layer Aspects”
[3] R1-092976, “Text proposal for relay backhaul link, macro-UE link channel model and relay evaluation methodologies for TR 36.814,” CMCC.
[4] R1-093117, “LOS Probability of the eNB-UE Direct Link”, Qualcomm Europe, Huawei, RIM.
[5] R1-093726, “Text proposal for channel model and evaluation methodology,” CMCC.
[6] R1-091456, “Initial evaluation of relay performance on DL”, Qualcomm Europe.
[7] R1-094229, “Techniques to maximize Type I relay gains”, Qualcomm Europe.