Backhaul Link Impact on the Admission Control in LTE-A Relay Deployment

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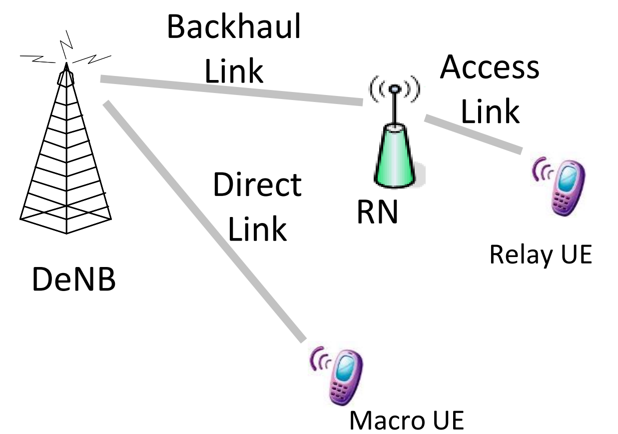
Outline

- Introduction and Problem Definition
- Admission Control Introduction
- Simulation Model
- Results
- Conclusions

Introduction and Problem Definition

Relay Node Introduction

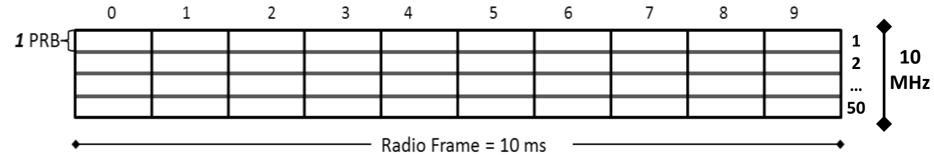
- Relay Nodes are deployed for:
  - Cell capacity enhancement
  - Coverage extension
- Involved Links:
  - Direct Link (DeNB-to-UE)
  - Backhaul Link (DeNB-to-RN)
  - Access Link (RN-to-UE)

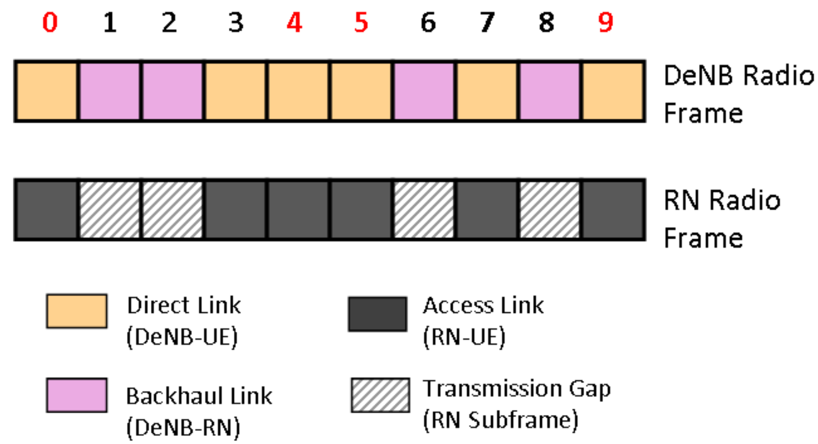


- In-band Relay Node:
  - DeNB and RNs use the same carrier frequencies
    - Necessity of resource partitioning to support time multiplexing
- Out-band Relay Node:
  - DeNB and RNs use different carrier frequencies

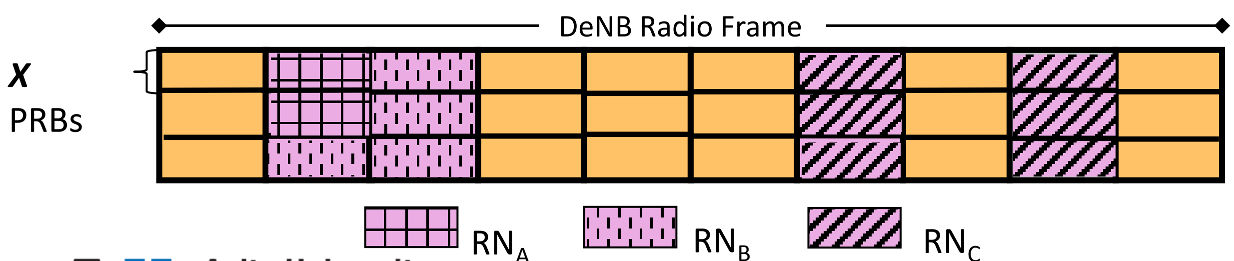
Radio Frame Configuration for In-band RNs

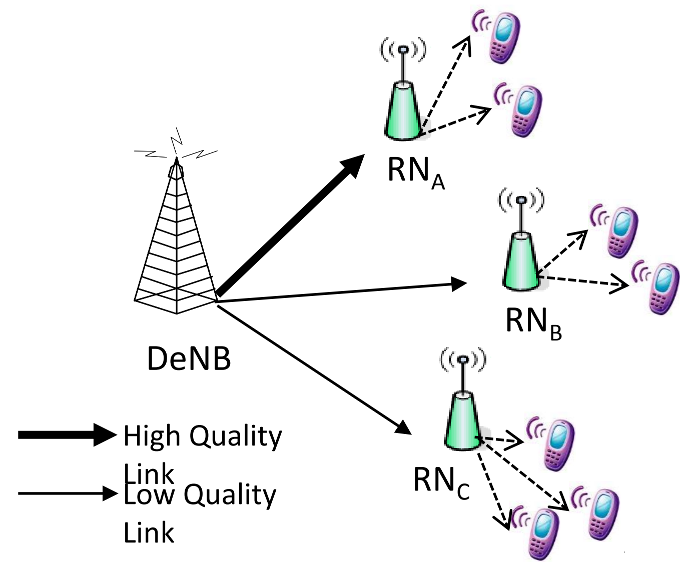
- Radio frame: 10 sub-frames of 1 *ms*
- 1 subframe per 180 kHz: 1 Physical Resource Block (PRB)
- DeNB and RNs resource partitioning
  - *M* RN subframes (max 6) reserved for backhaul link: $PRB_{BL} = M \times 50$
  - *(10 – M)* subframes reserved for access link and direct link: $PRB_{AL} = PRB_{DL} = (10 - M) \times 50$
    - Co-scheduling not implemented





- PRB_{BL} shared among RNs via dynamic resource sharing. The *r*-th RN gets PRB_{BLr} depending on:
  - Its backhaul link quality
  - Number of relay UEs connected to it.

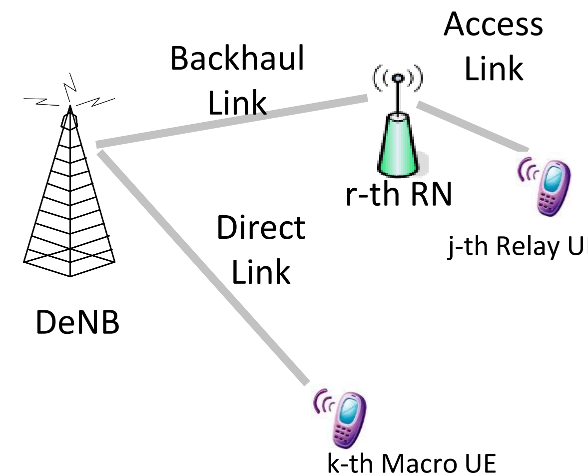




Admission Control Introduction

Resource Demand per Radio Frame

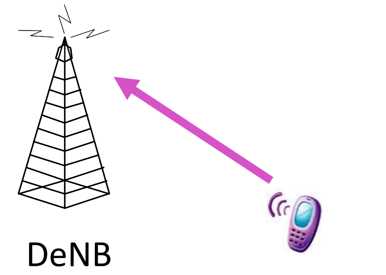
- Each UE demands a Constant Bit Rate (*R*). We computed the resources (PRBs) needed in one radio frame.
- The *k*-th macro UE needs
  - On the direct link : $PRB_{UE_k} = S \cdot \frac{R}{TP_{PRB_{UE_k}}}$
- The *j*-th relay UE needs
  - On the access link: $PRB_{UE_j} = S \cdot \frac{R}{TP_{PRB_{UE_j}}}$
  - On the backhaul link: $PRB_{UE_j RN_r} = S . \frac{R}{TP_{PRB_{RN_r}}}$



- $S = 10$ is the number of subframes scheduled in one radio frame
- $TP_{PRB_{UE_k}}$ is the throughput per PRB achieved by the *k*-th UE
- $TP_{PRB_{RN_r}}$ is the throughput per PRB achieved by the *r*-th RN.

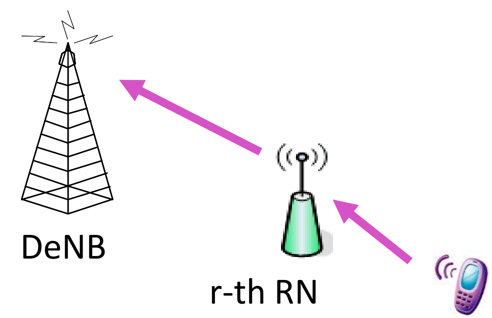
Admission Control Algorithm for In-band RNs

- Let's assume that (*k-1*) macro UEs are already accepted
- The *k*-th macro UE is accepted if:



  - $$PRB_{UE_k} \leq PRB_{DL} - \sum_{i=1 \ldots k-1} PRB_{UE_i}$$

- Let's assume that (*j-1*) relay UEs are already accepted by *r*-th RN
- The *j*-th relay UE is accepted if:



  - $$PRB_{UE_j} \leq PRB_{AL} - \sum_{i=1 \ldots j-1} PRB_{UE_i}$$
  - $$PRB_{UE_j RN_r} \leq PRB_{RL_r} - \sum_{i=1 \ldots j-1} PRB_{UE_i RN_r}$$

Motivations

In order to optimize the performance of in-band RNs the number of RN subframes has been properly selected

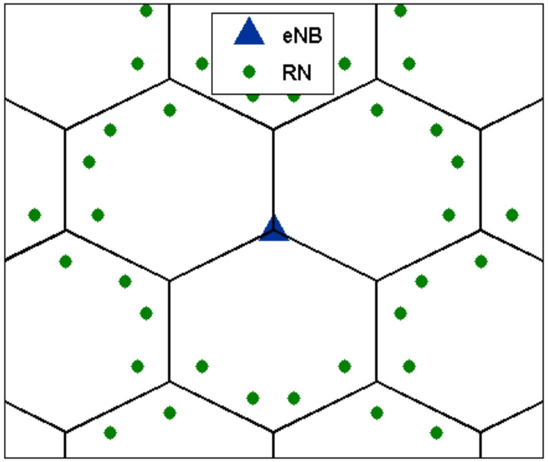
- The number of accepted relay UEs is limited by the capacity of the backhaul link
- In some scenario a shortage of resources on the direct link is provoked

Simulation Model

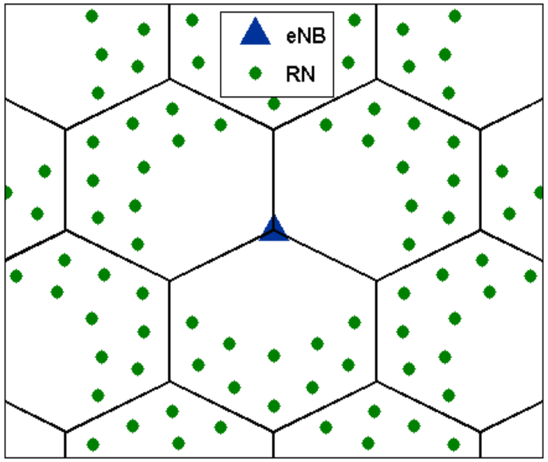
System Model

System Layout	19 tri-sectored sites
Bandwidth	10 MHz. 50 frequency slots of 180 kHz each
ISD	500 m (urban scenario) 1732 m (suburban scenario)
Relay Nodes	4, 10
CBR Traffic (R)	64, 128, 256, 512 kbps
Blocking Probability (β)	0.1%, 0.5%, 5 %
Users Drop	Uniform
Number of RN subframes (M)	1, 2, 3, 4, 5, 6
Channel Model	3GPP TR36.814 v9.0.0

4 RNs Deployment

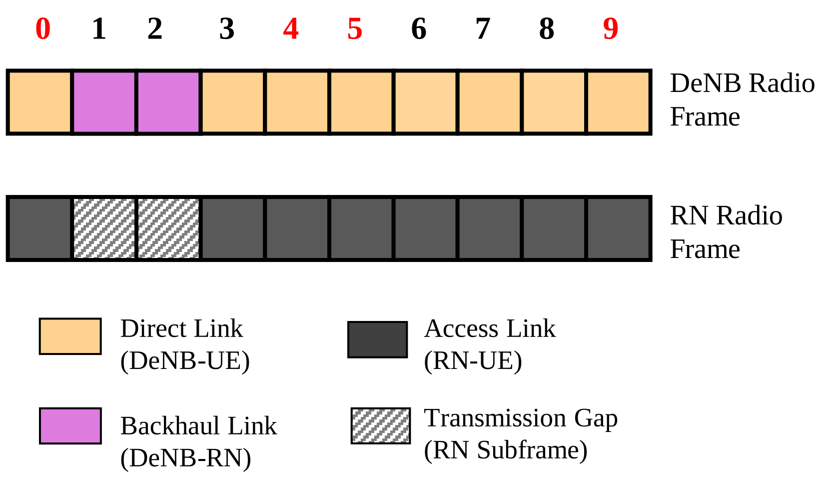


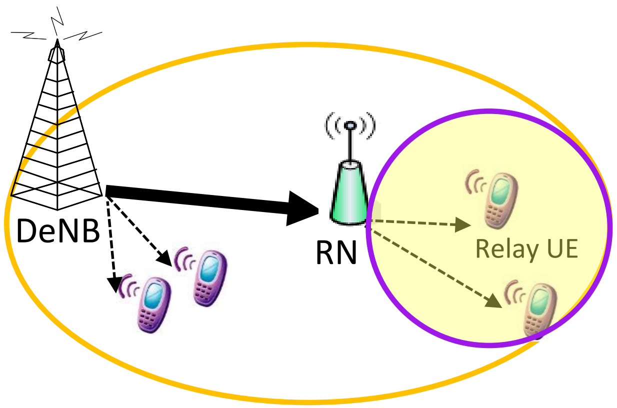
10 RNs Deployment



Study Case One – Ideal Backhaul Link

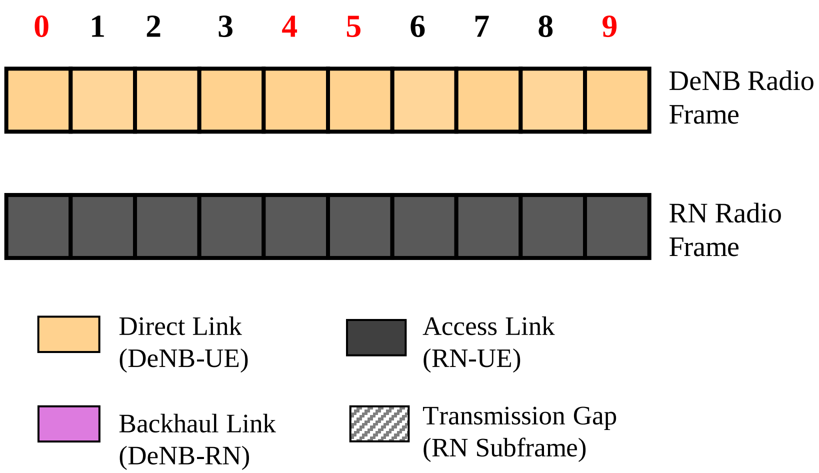
The RN subframes are reserved but the backhaul link capacity is so high that a relay UE is never rejected by the admission control on the backhaul link.

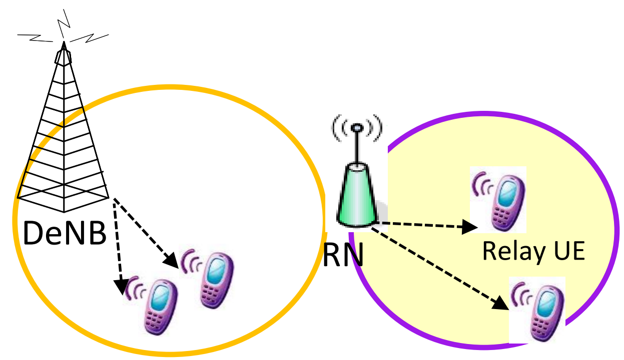




Study Case Two – Out-band RNs and Ideal Backhaul Link

We consider out-band RNs and a, such that the direct link and the access link have the full set of resources.





Results

RN Subframe Configuration in Different Scenarios Previous Results – In-band RNs

Urban Scenario **– Number of RN subframes (M)**

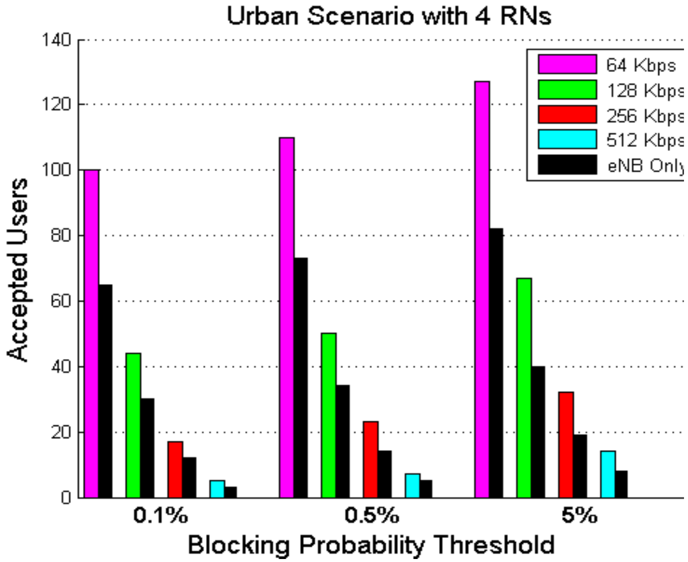
	4 Relay Nodes				**10 Relay Nodes**			
R / ***β***	*64 Kbps*	*128 Kbps*	*256 Kbps*	*512 Kbps*	*64 Kbps*	*128 Kbps*	*256 Kbps*	*512 Kbps*
0.1 %	2	2	2	2	4	3	3	3
0.5 %	2	2	2	2	4	4	3	3
5 %	2	2	2	2	4	4	4	4

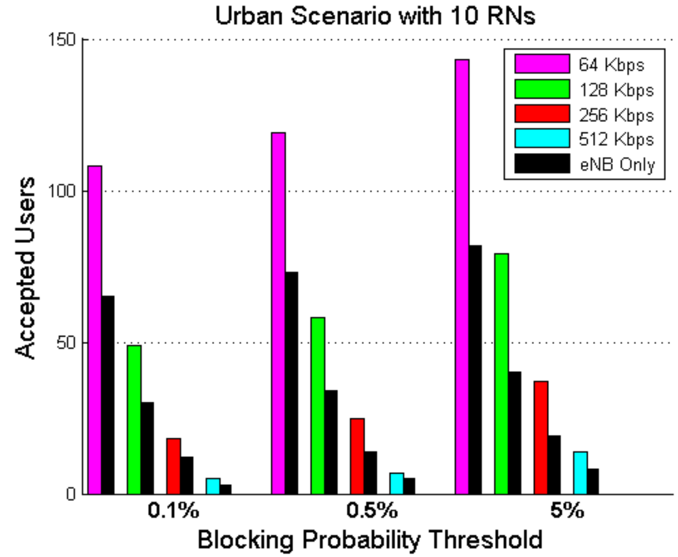
Suburban Scenario **– Number of RN subframes (M)**

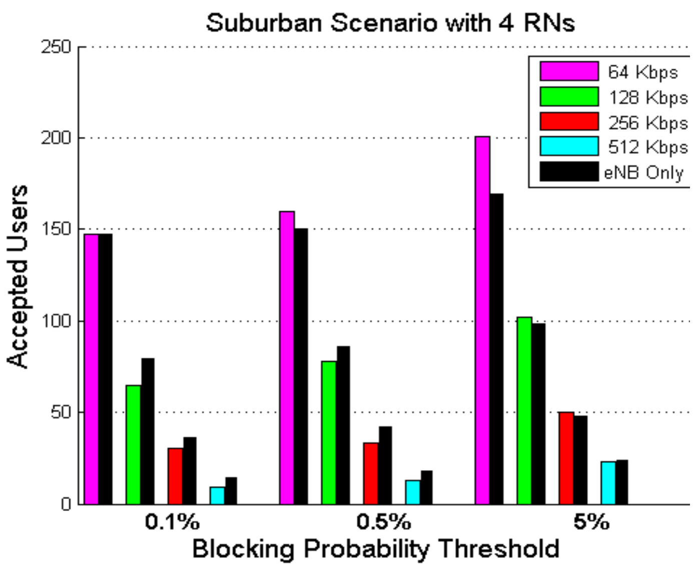
	4 Relay Nodes				**10 Relay Nodes**			
R / ***β***	*64 Kbps*	*128 Kbps*	*256 Kbps*	*512 Kbps*	*64 Kbps*	*128 Kbps*	*256 Kbps*	*512 Kbps*
0.1 %	2	2	2	2	5	4	4	4
0.5 %	2	2	2	2	5	5	4	4
5 %	2	2	2	3	5	5	5	5

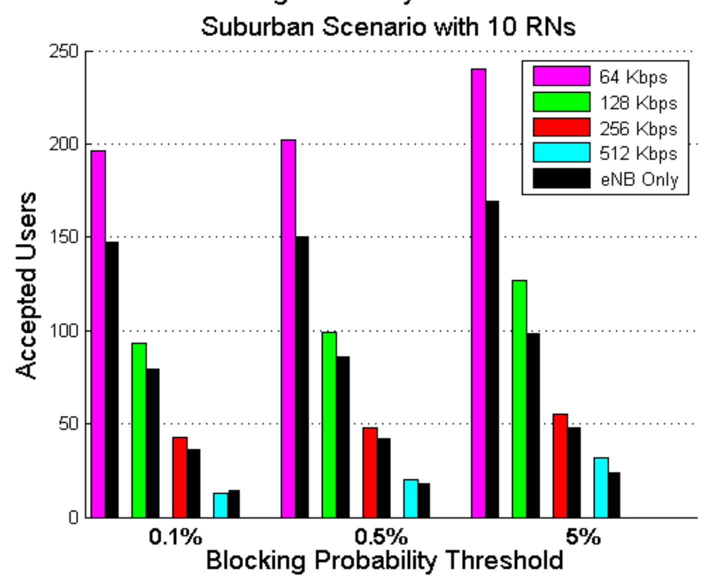
Accepted UEs in Different Scenarios
Previous Results – In-band RNs

For each blocking probability *β* and UE's bit rate *R*, we have assumed *M* which maximizes the number of accepted UE









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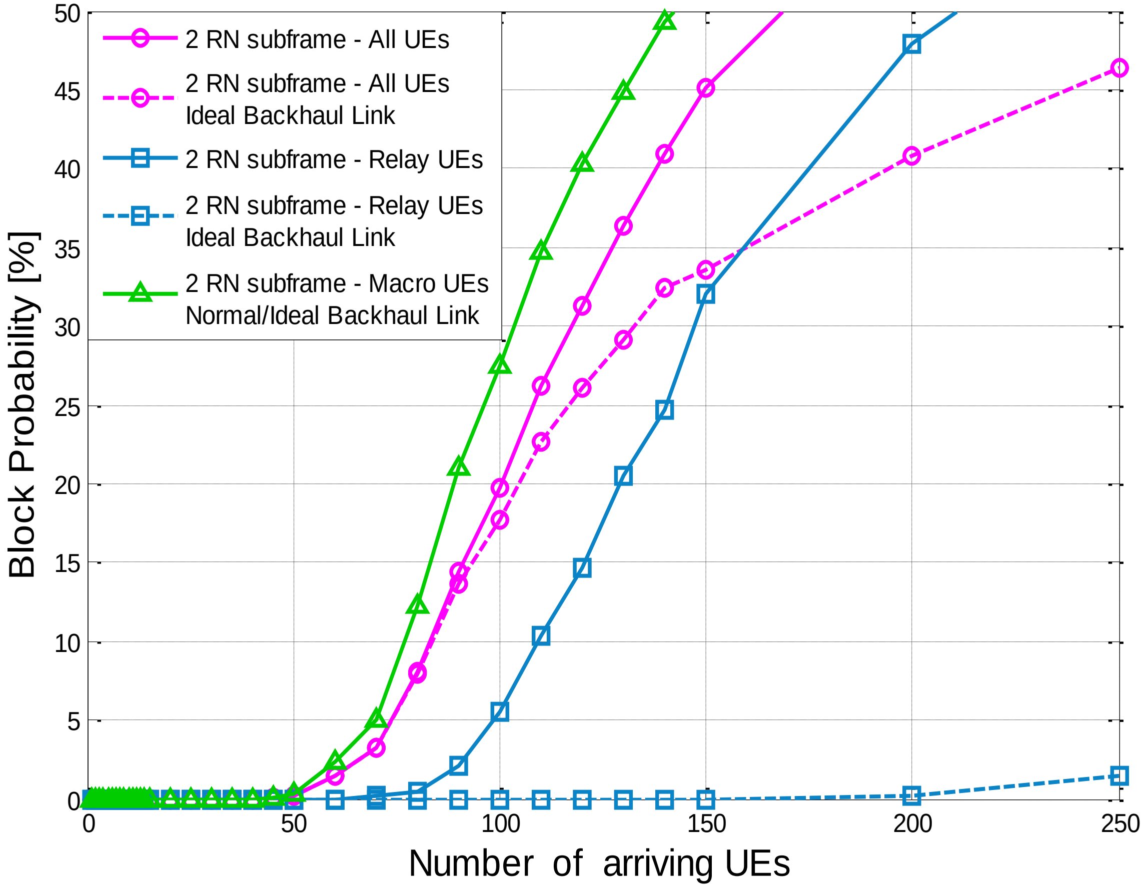
Study Case One – Ideal backhaul link

Urban Scenario with 4 RNs and a bit rate *R* = 128 Kbps.



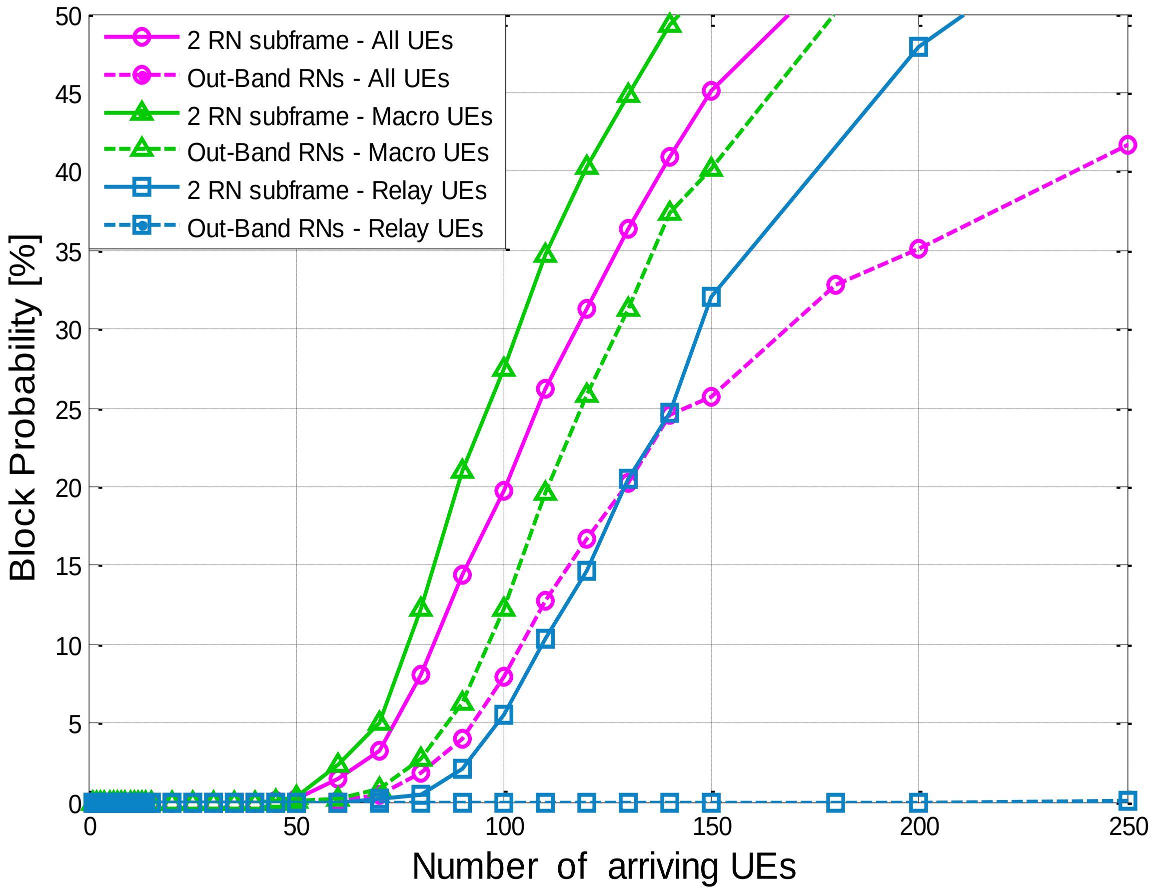
All UEs performance are influenced by macro and relay UEs.
With the ideal backhaul link, performance are influenced by Macro UEs

Ideal Backhaul Link doesn't impact Macro UEs

Relay UEs are limited by the backhaul link.

Study Case Two – Out-band RNs and Ideal Backhaul Link

Urban Scenario with 4 RNs and a bit rate *R* = 128 Kbps.



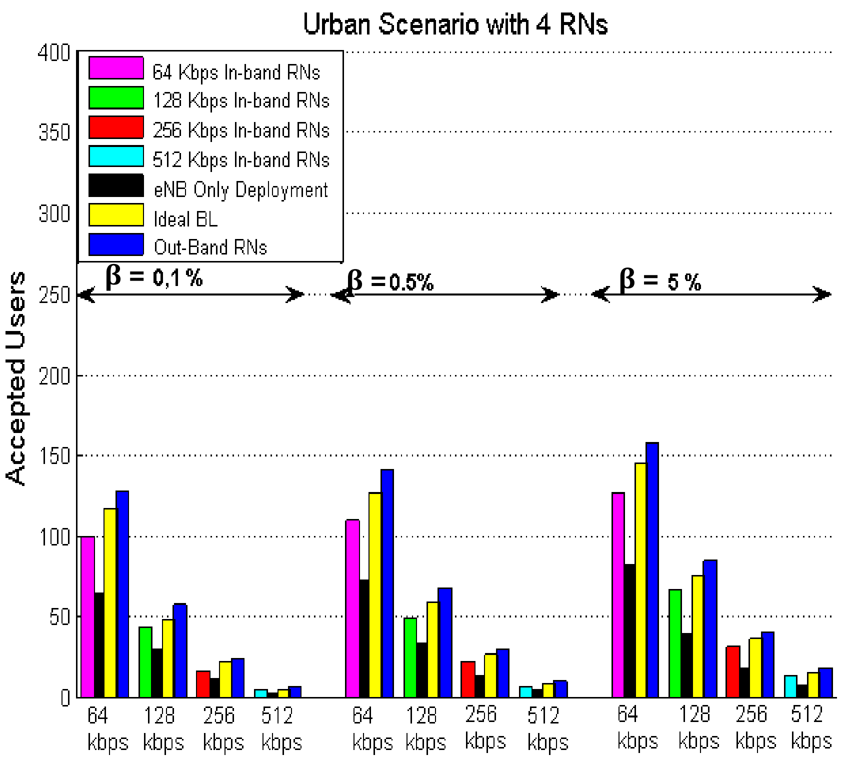
In case of Out-band RNs, the main blocking probability contribution is provided by macro UEs.

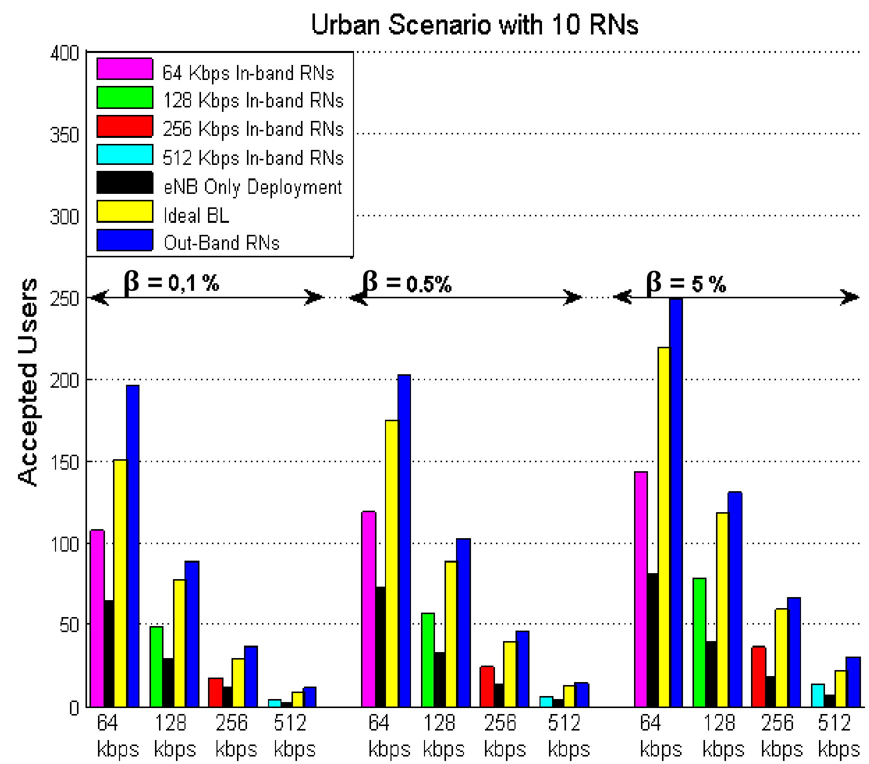
The Out-band RNs improve the Macro UEs performance.

Out-band RNs have a large impact on the Relay UEs.

Accepted UEs in Different Scenarios - Urban

For each blocking probability *β* and UE's bit rate *R,* we obtained a maximum number of accepted UE.

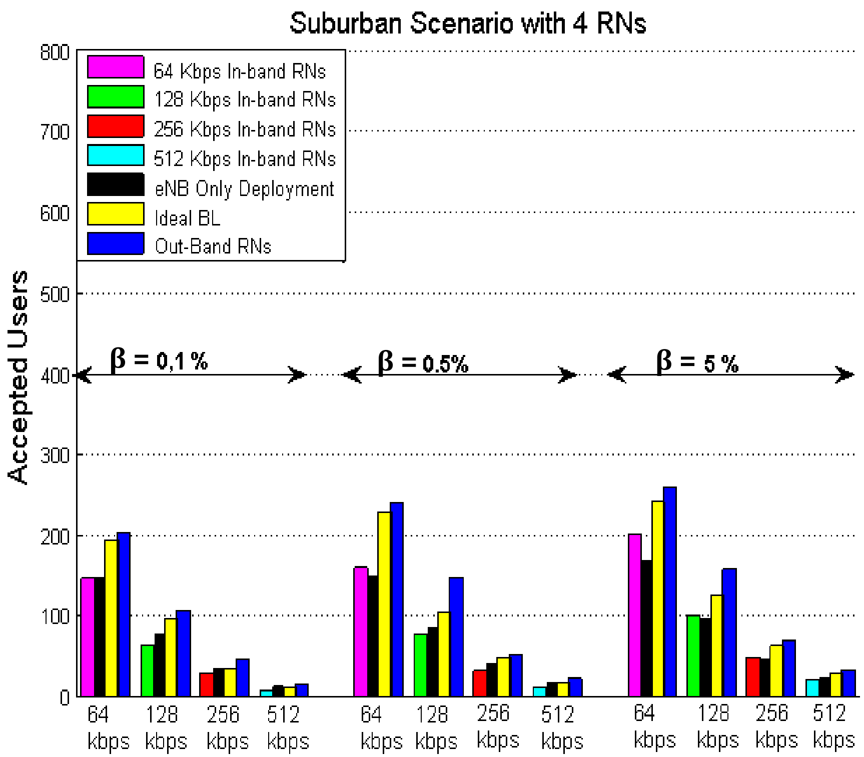


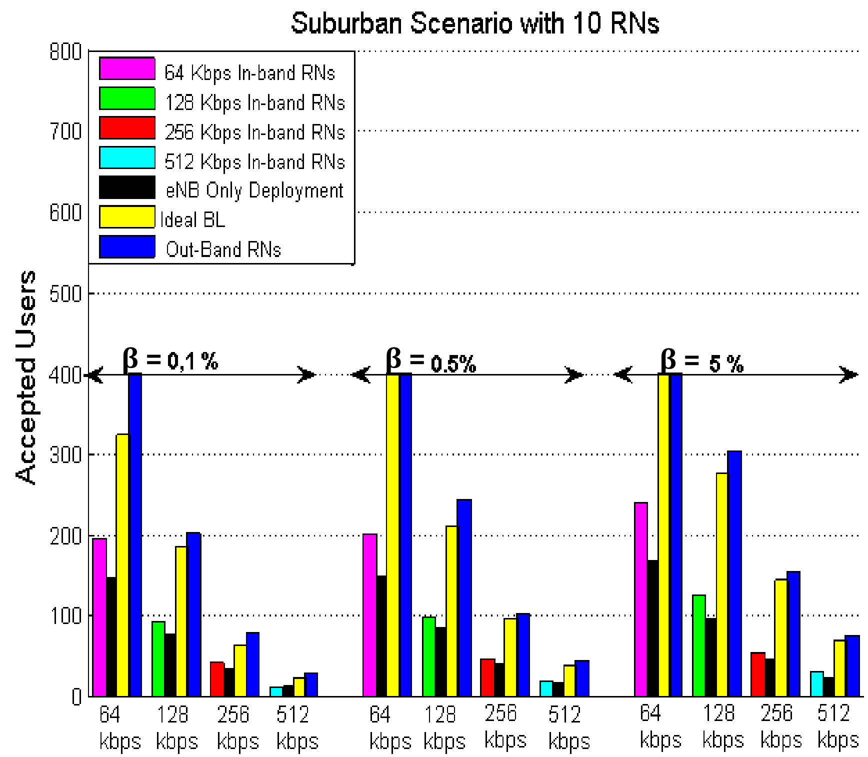


***β* is the set Blocking Probability Threshold**

Accepted UEs in Different Scenarios - Suburban

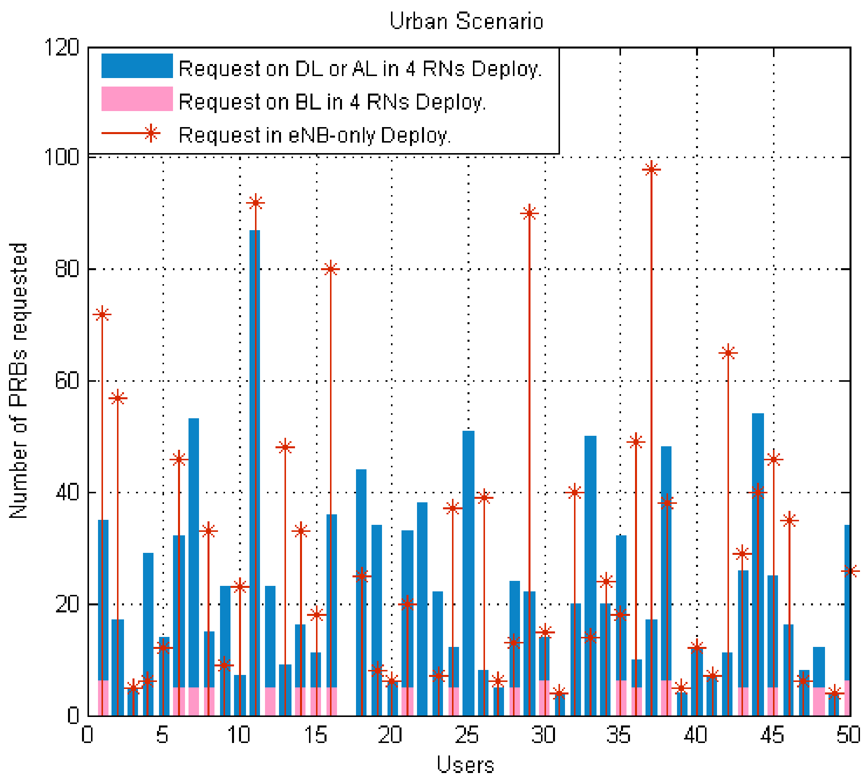
For each blocking probability *β* and UE's bit rate *R,* we obtained a maximum number of accepted UE.

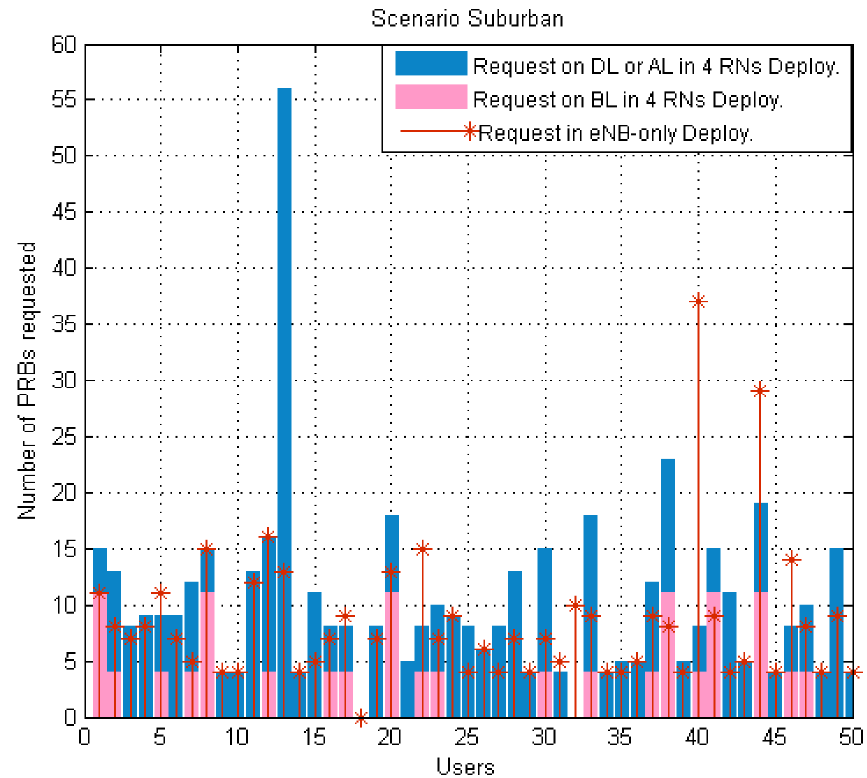




β **is the set Blocking Probability Threshold**

In-band RNs Introduction Impact





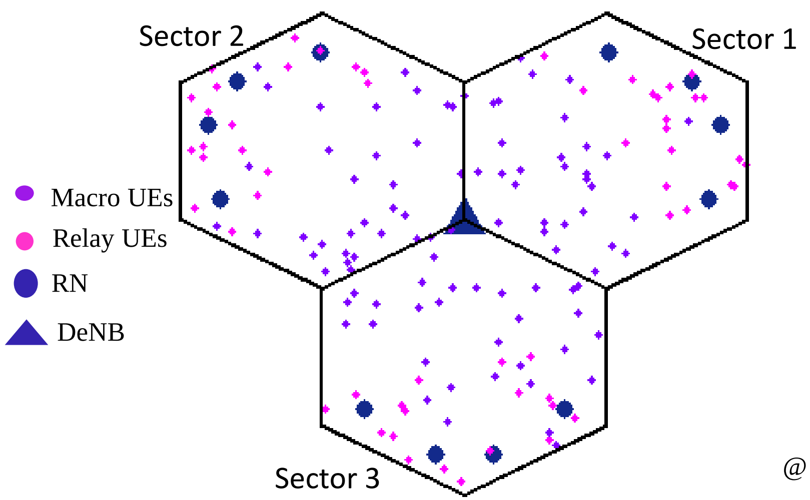
- In-band RNs' introduction brings remarkable gain in terms of the number of requested PRBs.

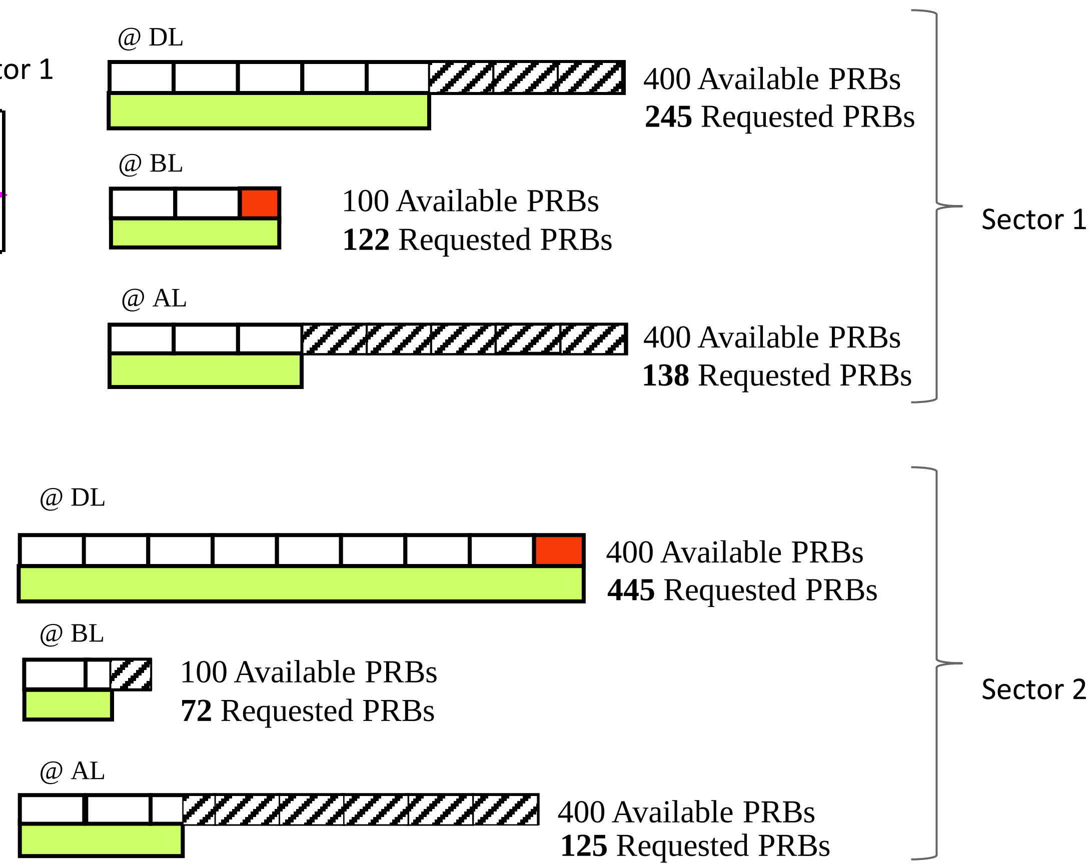
- In-band RNs' introduction does not bring remarkable gain in terms of the number of requested PRBs. But it provokes a shortage of resources.

Suburban Scenario Focus

In-band RNs → Resources' shortage:

- lack of resources on the backhaul link (e.g. Sector 1)
- lack of resources on the direct link (e.g. Sector 2)





Conclusions

Remarks

- An *ideal backhaul link* scenario with high capacity backhaul link increases the relay UEs acceptance rate.
- The introduction of *out-band RNs* improves the acceptance rate of relay UEs as well as of macro UEs.
  - If we use out-band RNs the impact on all UEs blocking probability is higher than the ideal scenario.
- In some scenarios the in-band RN deployment admits a smaller number of UEs compared to eNB only:
  - Mainly because of a lack of resources (backhaul link or direct link)
  - Lower SINR experienced (higher interference)

Thank you!

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