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Small cell enhancements for E-UTRA and E-UTRAN - Physical layer aspects
(Release 12)

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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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1 presented to TSG for information;

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Introduction

At the 3GPP TSG RAN #58 meeting (Dec 2012), the Study Item Description on "Small Cell Enhancements for E-UTRA and E-UTRAN – Physical-layer Aspects" was agreed for Release 12 [2].

This study covers the technologies for further enhancements of indoor and outdoor scenarios using low-power node, taking into account the scenarios and requirements for small cell enhancements captured in 3GPP TR 36.932 [3].

The present document covers the physical-layer aspects of these technologies.

1 Scope

The present document contains the result of the study item "Small Cell Enhancements for E-UTRA and E-UTRAN – Physical-layer Aspects" [1].
The purpose of the present document is to help TSG RAN WG1 to define and describe the potential physical layer small cell enhancements under consideration and compare the benefits of each enhancement technique, along with the complexity evaluation of each technique.

This activity involves the Radio Access work area of the 3GPP studies and has impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

The present document is intended to gather all information and draw a conclusion on a way forward.

The present document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TD RP-122032: "New Work Item Description for Study on Small Cell Enhancements for E-UTRA and E-UTRAN – Physical-layer Aspects ".

[3] 3GPP TR 36.932: "Scenarios and requirements for small cell enhancements for E-UTRA and E-UTRAN".

[4] RP-122033: "New Work Item Description for Study on Small Cell Enhancements for E-UTRA and E-UTRAN – Higher-layer aspects".

[5] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[6] 3GPP TR 36.922: "TDD Home eNode B (HeNB) Radio Frequency (RF) requirements analysis".

[7] 3GPP TS 32.592: "Telecommunication management; Home enhanced Node B (HeNB) Operations, Administration, Maintenance and Provisioning (OAM&P); Information model for Type 1 interface HeNB to HeNB Management System (HeMS)".

[8] 3GPP TR 36.842 draft V0.2.0, "Study on Small Cell Enhancements for E-UTRA and E-UTRAN – Higher layer aspects".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply.
A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

5 Small cell scenarios for evaluation

The scenarios for evaluation are described in this clause. Figure 5-1 shows the common design for scenarios. It is noted that actual deployment of small cells are described in [3]. The scenarios described in the clause are the subsets for the evaluation purpose. It is also noted that the addition of scenarios for evaluation of higher-layer aspects can be considered depending on the outcome of the higher-layer studies.

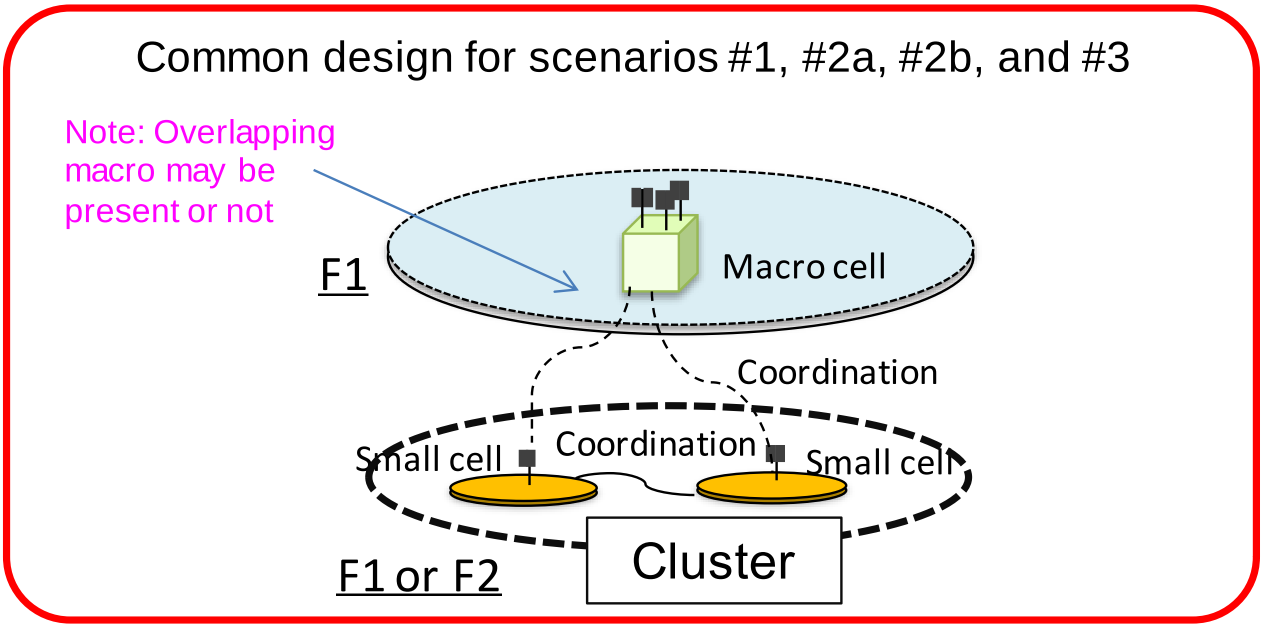


Figure 5-1: Small cell deployment scenario for evaluation

5.1 Scenario #1

Definition of SCE scenario #1 is provided below.

- The small cells are deployed in the presence of an overlaid macro network
- Co-channel deployment of the macro cell and small cells
- Outdoor small cell deployment
- Small cell cluster is considered
  - The small cells of a cluster are denser than scenarios considered for Rel-10 eICIC, Rel-11 FeICIC/ CoMP
    - Details regarding the number/ density of small cells per cluster, backhaul assumptions for the evaluation of coordination techniques among small cells and time synchronization assumptions among small cells are provided in Annex A
- Both ideal backhaul and non-ideal backhaul are considered for the following interfaces:
  - between the small cells within the same cluster
  - between a cluster of small cells and at least one macro eNB
- Non-ideal backhaul is assumed for all other interfaces

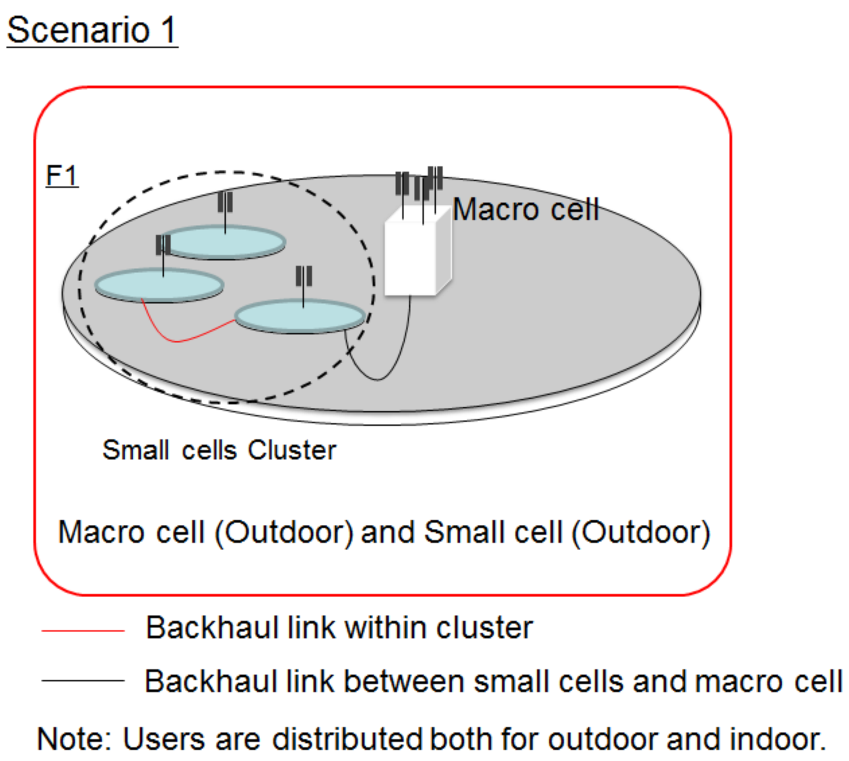


Figure 5.1-1: Small cell deployment scenario #1

5.2 Scenario #2a

Definition of SCE scenario #2a is provided below.

- The small cells are deployed in the presence of an overlaid macro network
- Separate frequency deployment of the macro cell and small cells
- Outdoor small cell deployment
- Small cell cluster is considered
    - The small cells of a cluster are denser than scenarios considered for Rel-10 eICIC, Rel-11 FeICIC/ CoMP
        - Details regarding the number/ density of small cells per cluster, backhaul assumptions for the evaluation of coordination techniques among small cells and time synchronization assumptions among small cells are provided in Annex A.
- Both ideal backhaul and non-ideal backhaul are considered for the following interfaces:
    - between the small cells within the same cluster
    - between a cluster of small cells and at least one macro eNB
- Non-ideal backhaul is assumed for all other interfaces

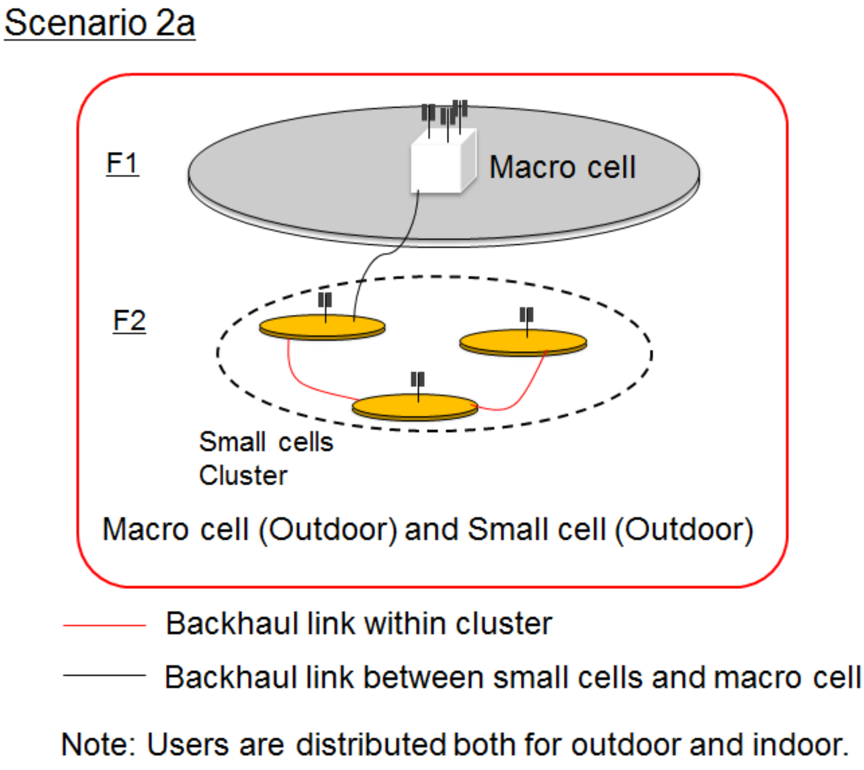


Figure 5.2-1: Small cell deployment scenario #2a

5.3 Scenario #2b

Definition of SCE scenario #2b is provided below.

- The small cells are deployed in the presence of an overlaid macro network
- Separate frequency deployment of the macro cell and small cells
- Indoor small cell deployment
- Small cell cluster is considered
  - The small cells of a cluster are denser than scenarios considered for Rel-10 eICIC, Rel-11 FeICIC/ CoMP
    - Details regarding the number/ density of small cells per cluster, backhaul assumptions for the evaluation of coordination techniques among small cells and time synchronization assumptions among small cells are provided in Annex A.
  - A sparse scenario can be considered such as the indoor hotspot scenario evaluated for Rel-10 scenarios.
- Both ideal backhaul and non-ideal backhaul are considered for the following interfaces:
  - between the small cells within the same cluster
  - between a cluster of small cells and at least one macro eNB
- Non-ideal backhaul is assumed for all other interfaces

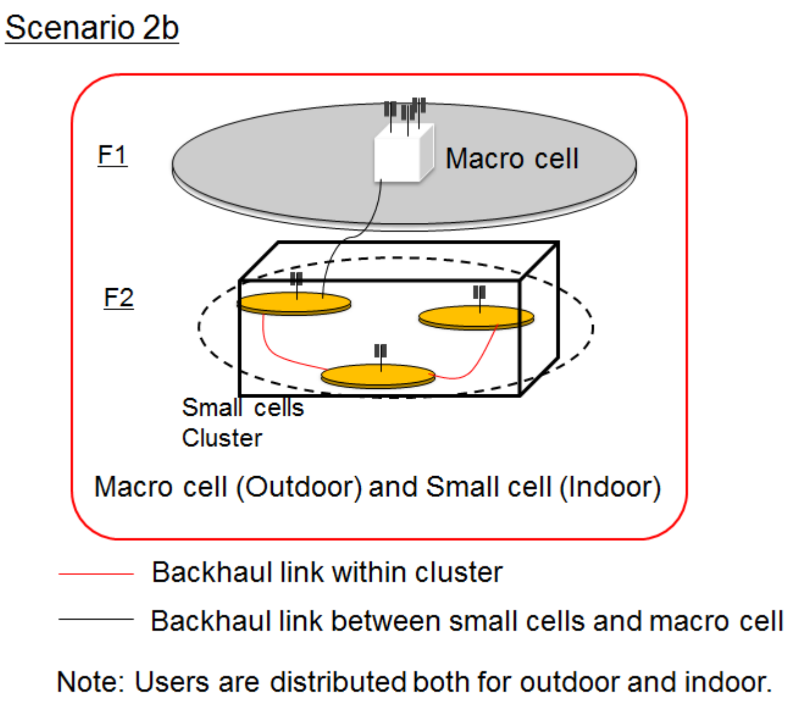


Figure 5.3-1: Small cell deployment scenario #2b

5.4 Scenario #3

Definition of SCE scenario #3 is provided below.

- Macro cell coverage is not present
- Indoor deployment scenario
- Small cell cluster is considered
    - The small cells of a cluster are denser than scenarios considered for Rel-10 eICIC, Rel-11 FeICIC/ CoMP
        - Details regarding the number/ density of small cells per cluster, backhaul assumptions for the evaluation of coordination techniques among small cells and time synchronization assumptions among small cells are provided in Annex A.
    - A sparse scenario can be considered such as the indoor hotspot scenario evaluated for Rel-10 scenarios.
- Both ideal backhaul and non-ideal backhaul are considered for the following interfaces:
    - between the small cells within the same cluster
- Non-ideal backhaul is assumed for all other interfaces

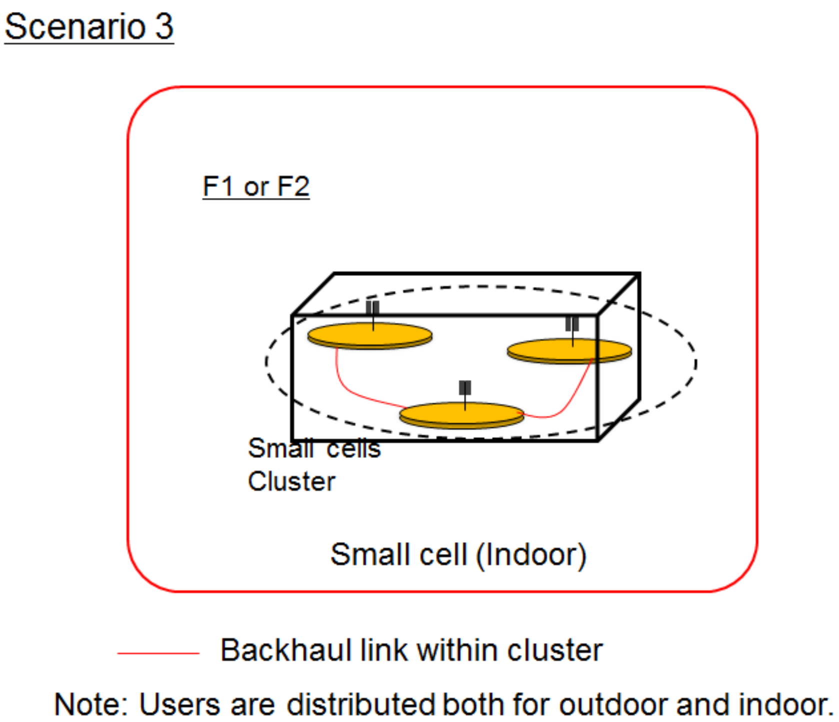


Figure 5.4-1: Small cell deployment scenario #3

Within scenarios 2b and 3, all features will at least be evaluated in the dense cases. Note that this does not preclude evaluation being carried out equally in other cases for particular features. It is recommended that spectral efficiency enhancements should be evaluated in sparse cases as well.

6 Potential enhancements to improve spectrum efficiency

6.1 Introduction of a higher order modulation scheme for the downlink

The high geometry experienced by UEs in some small cell deployments provides the possibility for introducing higher order modulation scheme (i.e. 256 QAM) for the downlink transmission. In this section, the potential gain of introducing 256QAM is summarized from both link level and system level perspectives.

The link level evaluation results are summarized in Table 6.1-1. The system level evaluation results are summarized in Table 6.1-2. The evaluations are performed according to the assumptions shown in Annex A.3. Rx EVM and impairment modelling including Rx IQ imbalance are used to model Rx impairments, unless described otherwise. In both tables, the entries without explicitly mentioning Rx impairment modelling refer to the cases that no Rx impairments is modelled. Different Rx EVM modelling may be used in the simulations.

In table 6.1-2, the entries without mentioning CRS interference refer to the cases that CRS interference is not modelled.

Table 6.1-1 Link level evaluation results of 256QAM

	SINR range in which a gain is observed	Observed maximum spectrum efficiency gain		
		0% Tx EVM	4% Tx EVM	6% Tx EVM
Source 1	>27dB (rank adaptation, 0% or 4% Tx EVM)	33%	30%(0% Rx EVM) 15%(2% Rx EVM)	
Source 2	>25dB (rank2, 0% or 4% Tx EVM)	33%	15%	2%
Source 3	>30dB(rank2) >20dB(rank1)	33% (rank2) 33% (rank1)	17%(rank2) 25%(rank1)	
Source 4	>30dB(rank2, TM3) >36dB(rank2, TM3, 4% Tx EVM)	30%(TM3, @38dB) *	3%(TM3, @38dB) *	-30% (TM3)
Source 5	>25 dB(rank adaptation, 0% or 4% Tx EVM)	25%(@40dB)*	10%(@40dB)* 8% (2% Rx EVM, @40dB) * 3%(4% Rx EVM)	1%
Source 6	>25 dB(rank2, 0% or 4% Tx EVM) >18 dB(rank1, 0%, 4% or 6% Tx EVM)	15%*(rank2, @30dB) * 33% (rank1)	10% (rank2, @30dB) * 29%(rank1)	-4%(rank2) 25%(rank1)
Source 7 (fixed coding rate of 5/6)	>30dB(0% Tx EVM, rank 2) >38dB(4% Tx EVM, rank2)	25% (rank 2) -13% (rank2, RX IQ imbalance with -25dB IMRR)	10% (rank2) -9% (rank2, RX IQ imbalance with -25dB IMRR)	-30% (rank2) -3% (rank2, RX IQ imbalance with -25dB IMRR)
Source 8	>27dB(rank adaptation, 0% Tx EVM) >30dB(rank adaptation, 4% Tx EVM)	23.1%(@40dB)*	9.4%(@40dB)* 0%(4% Rx EVM)	
Source 9	>28dB (rank2) >24dB (rank1)	20%(rank2, @32dB) * 30% (rank1, @32dB) *	15%(@32dB)*	0%
Source 10	>22dB dB (rank1)	28% (rank1, @32dB) *	15% (rank1)	

NOTE: The throughput curves are not saturate yet within the evaluated SNR region

Table 6.1-2 Observed cell average UPT gain of 256QAM with 4% Tx EVM

Cell average gain on UPT	
Source 1 **RU = 30%**	Rx EVM = 0% : 27%(in S3 sparse) : 13%(in S3 sparse, with CRS interference) 14% (in S2a) 4% (in S2a, with CRS interference) 22% (in S2b sparse) 12% (in S2b sparse, with CRS interference) Rx EVM = 2%: 19%(in S3 sparse) 8%(in S3 sparse, with CRS interference) 10% (in S2a) 4% (in S2a, with CRS interference) 15% (in S2b sparse) 9% (in S2b sparse with CRS interference)
Source 3 **50% UPT performance**	16%(in S2b sparse, RU=10%) 13%(in S2b sparse, RU=30%) 12%(in S2b dense, RU=10%) 9%(in S2b dense, RU=30%)
Source 6	9% ~ 22% (in S2b dense, RU: 77% ~ 18%) 6% ~ 20% (in S2a, RU: 26% ~ 8%) ~ 6% (in S2b dense, RU: 23% ~ 80%, with CRS interference) ~ 5% (in S2a, RU: 13% ~33%, with CRS interference)
Source 8	All UEs: 8 ~ 10% (in S2a, 0% Rx EVM, RU : 37% ~ 9%) 4.4% ~ 7.5% (in S2a, 4% Rx EVM, RU: 40% ~ 11%) Small cell UEs: 10% ~13% (in S2a, 0% Rx EVM, RU : 24% ~5%) 8 %~ 6% (in S2a, 4% Rx EVM, RU : 27% ~ 6%)
Source 11	24%(in S3 sparse, RU : not provided)
Source 12	11%(in S3 sparse, 4% Rx EVM, RU : 17.5%) 22.5 %(in S3 sparse, 3% Tx EVM, 3% Rx EVM, RU : 17.5%)
Source 13 (note)	15%(in S3 sparse, 4% Rx EVM, RU : ~25%, with CRS interference) 6%(in S3 sparse, 6% Rx EVM, RU : ~25%, with CRS interference)
NOTE: The Tx EVM is not modelled.	

The evaluation results show that:

- The potential gains of 256 QAM are dependent on Tx EVM being around 4% or less, and are more sensitive to practical Rx impairments, especially IQ imbalance, than to Tx EVM.
- In the link level simulations, the minimum SINR for which a gain is observed is around 18dB~24dB with rank1 transmission. For transmission with rank 2 or with rank adaptation, with 0% Tx EVM, the minimum SINR for which a gain is observed is around 25dB~30dB. For transmission with rank 2 or with rank adaptation, with 4% Tx EVM, seven sources show the minimum SINR for which a gain is observed is around 25dB~30dB, two companies show the minimum SINR is around 36dB~38dB.
- In the link level simulations, when Tx EVM and Rx impairments are not modelled, the observed maximum spectrum efficiency gain is 15%~33%. When Tx EVM is assumed to be 4%, the observed maximum spectrum efficiency gain is 10%~30% without considering Rx impairments. One source shows 3% maximum spectrum efficiency gain without considering Rx impairments. According to the sources with Rx impairment modelled as Rx EVM, the observed maximum spectrum efficiency gain degrades when Rx impairment is modelled. According to the one source with modelling of Rx IQ imbalance with -25dB IMRR, no gains from 256QAM were observed.
- In the system level simulations, most of the simulations were performed with 4% Tx EVM assumed. 6%~27% gain on cell average UPT is observed for scenarios of S3 sparse and S2b sparse; 4%~22% gain on cell average UPT is observed for the scenarios of S2a and S2b dense. Simulation results with CRS interference modelled are worse than the results without CRS interference modelled.

Supporting 256QAM has standards impacts on:

- eNB Tx EVM and UE impairment in RAN4
- CQI/MCS/TBS tables

- Mechanism for the eNB to select and inform the UE whether the new CQI/MCS/TBS tables are used
  PUCCH and PDCCH/EPDCCH design if larger UCI/DCI payload size is used.

6.2 Enhancements and overhead reduction for UE-specific reference signals and control signalling

The channel characteristics of small cells that are relevant to the enhancements considered in this clause include

- Low frequency-selective fading channel with small delay spread.
- In cases when the UE mobility is low, the time-selective fading is also low.

In this clause, the discussion is focused on the techniques of enhancements and overhead reduction for UE-specific reference signals and control signalling to better match the scheduling and feedback in time and/or frequency to the channel characteristics of small cells. The techniques are in both downlink and uplink based on existing channels and signals.

6.2.1 Overhead reduction of downlink UE-specific reference signal

The low frequency-selective and low time-selective fading provides the possibility for overhead reduction of downlink UE-specific reference signal.

Evaluations on spectrum efficiency gain have been performed with the assumptions shown in Annex A.3.
The baseline downlink UE-specific reference signal with port 7 and port 8 is shown in Figure 6.2.1-1 [5].
The overhead reduction is considered in the time and/or frequency domain.

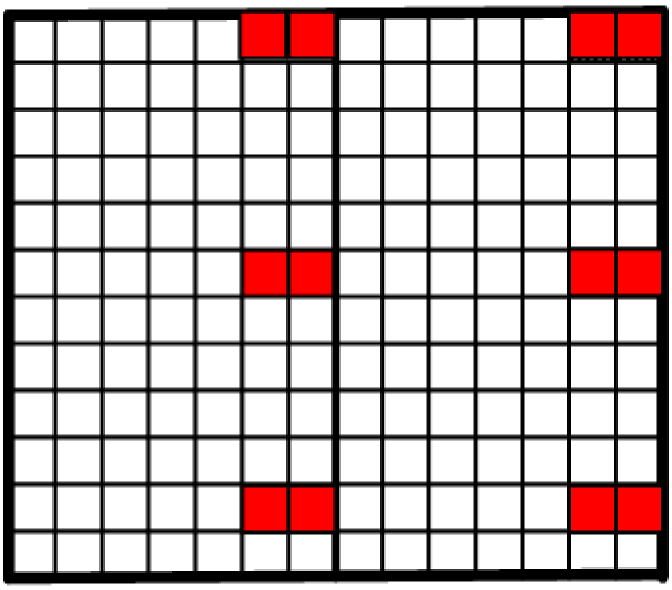


Figure 6.2.1-1 Baseline downlink UE-specific reference signal with port 7 and port 8

The evaluation results are summarized in Table 6.2.1-1 and Table 6.2.1-2.

Table 6.2.1-1 SINR range in which the spectrum efficiency gain is observed

Source	SINR range in which the gain is observed
Source 1	>5dB
Source 2	>5dB
Source 3	>2 dB
Source 4	>16dB for 64QAM
Source 5	>20dB with PRB bundling
Source 6	>17dB
Source 7	>23dB without PRB bundling
	>5dB with 3 PRB bundling
	>5dB with 6 PRB bundling
Source 8	>10dB for rank 1 >20dB for rank 2
Source 9	>15dB
Source 10	>20dB
Source 11	>15dB
Source 12	>2dB
Source 13	>21dB
Source 14	>20dB

Table 6.2.1-2 Observed spectrum efficiency gain

SINR	Average gain
5dB	0.9%
20dB	2.4%
30dB	3.9%

The evaluation results show that:

- Any gains from overhead reduction of downlink reference signal occur mainly at high SINR range.
- Gain/loss is dependent on various factors including:
    - PRB bundling size
    - UE speed
    - Modulation scheme
    - Transmission rank
    - TX/RX impairments including EVM
- Real interference modelling/estimation is important, especially for advanced receivers

Supporting the overhead reduction of downlink reference signal has the following specification impacts:

- The pattern design of the reduced reference signal
- Signalling to inform the UE of using the reduced reference signal

A suitable mechanism by which the eNB can select the downlink reference signal pattern would also need to be identified.

6.2.2 Overhead reduction of uplink UE-specific reference signal

The low frequency-selective and low time-selective fading channel in small cells provides the possibility for overhead reduction of uplink UE-specific reference signal.

Evaluations on spectrum efficiency gain have been performed with the assumptions shown in Annex A.3.
The baseline uplink UE-specific reference signal is shown in Figure 6.2.2-1[5].
The overhead reduction is considered in the time and/or frequency domain, the main methods proposed being:

- reduction of number of the reference signal symbols per subframe
- reduction of number of subcarriers carrying the reference signal

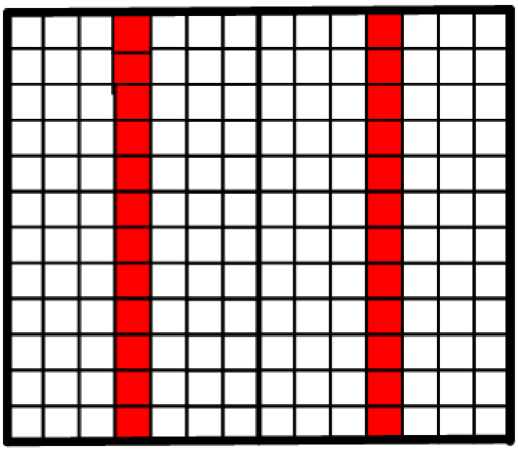


Figure 6.2.2-1 Baseline uplink UE-specific reference signal

The evaluation results are summarized in Table 6.2.2-1 and Table 6.2.2-2 for reduction of the number of reference signal symbols per subframe.

Table 6.2.2-1 SINR range in which the spectrum efficiency gain is observed

Source	SINR range in which the gain is observed
Source 1	>3dB
Source 2	>0dB
Source 3	>3dB
Source 4	>0dB
Source 5	>-1dB

Table 6.2.2-2 Observed spectrum efficiency gain

SINR	Average gain
3dB	7.8%
10dB	8.7%
20dB	6.4%

It is observed from the evaluation that

- Around 7% spectrum efficiency gains are observed with only 1 reference signal symbol per subframe at medium and high SINR range and low UE mobility
- There is a large spread between the results of different sources.

Implementation issues also need to be considered, including PAPR/CM consideration in case of reduction of number of subcarriers carrying the reference signal.

If the method involves reduction of the number of reference signal symbols per subframe, the impact on MU scheduling would need to be considered.

Supporting the overhead reduction of uplink reference signal may have the following specification impacts:

- The pattern design of the reduced reference signal
- The mapping of the reduced reference signal in the case of reduction of number of subcarriers carrying the reference signal
- Signalling to inform the UE of using the reduced reference signal
- OCC design in case of reduction of the number of reference signal symbols per subframe
- Group hopping design in case of reduction of the number of reference signal symbols per subframe
- UCI mapping design
- PUSCH RE mapping

A suitable mechanism by which the eNB can select the uplink reference signal pattern would also need to be identified.

6.2.3 Enhancements of control signalling

6.2.3.1 Multi-subframe scheduling and cross-subframe scheduling

Multi-subframe scheduling and cross-subframe scheduling have been considered as possible control signalling overhead reduction techniques

- There are diverse views on the usefulness and potential gains of these methods, and possibilities for achieving significant gains have not been identified
- It has been noted that PDSCH transmission in OFDM symbol #0 is strongly related to realising possible downlink gains from these methods
- These methods may facilitate the scheduling of PUSCH e.g. in ABSs.

Supporting multi-subframe and/or cross-subframe scheduling may have the following specification impacts:

- The timing between DL grant and PDSCH
- The timing between UL grant and PUSCH, as well as the timing between PUSCH and PHICH
- The maximum number of HARQ process and the corresponding UE soft buffer handling
- The necessary DCI format
- Signalling to configure multi-subframe/cross-subframe scheduling
- HARQ-ACK resource allocation
- Possible PDCCH/EPDCCH blinding decoding
- Mechanism to override or interrupt a multi-subframe/cross-subframe scheduling assignment

6.2.3.2 Transmission of PDSCH/ePDCCH in OFDM symbol #0

Transmission of PDSCH/EPDCCH in OFDM symbol #0 has been considered

- A gain in PDSCH RE availability can be achieved by this method in subframes in which it can be performed, e.g. up to 5.5% in PDSCH PRB pairs in MBSFN subframes with 2 CRS ports configured and rank 1-2 transmission, or up to 6% in PDSCH PRB pairs in non-MBSFN subframes, with 2 CRS ports configured, with DMRS based transmission modes
- The proportion of subframes in which this gain can be achieved is FFS.
- There are diverse views on the complexity and potential gains of this method.
- It is noted that reliable dynamic signalling for PDSCH starting in OFDM symbol #0 is only available using a mechanism similar to the PQI signalling introduced in TM10.

Supporting the PDSCH/EPDCCH from the first OFDM symbol may have the following specification impacts:

- Signalling to inform the UE of the PDSCH/EPDCCH starting symbol
- Mechanism(s) to maintain backward compatibility

7 Mechanisms to ensure efficient operation of a small cell layer

7.1 Mechanisms for interference avoidance and coordination among small cells

For each technique of interference avoidance and coordination, further study includes the followings:

- Feasible time scale (i.e., how fast or slow the technique is applied)
- Performance analysis/gain
- Necessary enhancements of mechanism and procedure, and additional measurements to help the network decision
- Consideration on its potential impacts on other system performance, for example, coverage, increased handover and signalling, energy consumption, possible impact on IDLE mode UEs

Candidate techniques for study are listed in following subclauses, other techniques are not precluded.

7.1.1 Small cell on/off

A small cell can also refer to a component carrier when more than one component carrier is available.

This work continues under this Study, with the findings being taken later into account in the NCT(New Carrier Type) Work Item.

7.1.1.1 Small cell on/off schemes and performance gains

The following schemes are relevant to small cell on/off study:

1) Baseline schemes without any on/off

In these schemes, the small cell is always on.

2) Long-term on/off schemes for energy saving

In these schemes, the small cells may be turned on/off in large time scales. These schemes are studied in RAN3 Energy Saving SI/WI.

3) Semi-static on/off schemes

In these schemes, the small cells may be turned on/off semi-statically. The descriptions of the schemes and their performance evaluations are included in 7.1.1.1.1.

4) Ideal, dynamic on/off schemes

In these schemes, the small cells may be turned on/off in subframe level. The descriptions of the schemes and their performance evaluations are included in 7.1.1.1.2.

5) NCT with NCTCRS (i.e., reduced CRS)

NCT with NCTCRS is studied in NCT WI. Small cell on/off developed in SCE can apply to NCT after it is introduced. Comparison NCTCRS and small cell on/off performance are included in 7.1.1.1.3.

7.1.1.1.1 Semi-static small cell on/off schemes and performance gains

In these schemes, the small cells may be turned on/off semi-statically. The criteria used for semi-static on/off may be the traffic load increase/decrease, UE arrival/departure (i.e. UE-cell association), and packet call arrival/completion. With legacy procedures, the feasible time scales of semi-static on/off schemes are generally in the order of seconds to hundreds of millisecond level; and with possible enhancements, the transitions may reduce to tens of milliseconds if all UEs connected to the cell are at least of Rel. 12.

a) Semi-static on/off scheme based on traffic load

In this case, a turned-off small cell may be turned on if the traffic load in a neighbourhood of the cell (including the cell itself) increases to a certain level. Conversely, a turned-on small cell may be turned off if the traffic load in a neighbourhood of the cell decreases to a certain level.

The performance gains for semi-static on/off based on traffic load for Scenario 2a with 10picos/macro are summarized in Table 7.1.1.1.1-1.

Table 7.1.1.1.1-1 Performance gains for semi-static on/off based on traffic load (Scenario 2a with 10picos/macro)

Off ratio range	Source	On/off parameters/setting	UPT gains				FTP model	MBSFN	Traffic load
			Mean	5%ile	50%ile	95%ile			
Low turn-off ratio (20%off)	1 (R1-132890)	random 20% off		6%	6%		3	0	0.2 file/s/UE
	2 (R1-133324)	random 20% off	9%	-2%	19%	0%	1	0	0.3 file/s/UE
	1 (R1-132890)	random 20% off		5%	6%		3	0	0.4 file/s/UE
Medium turn-off ratio (40%off)	1 (R1-132890)	random 40% off		10%	11%		3	0	0.2 file/s/UE
	2 (R1-133324)	random 40% off	21%	27%	90%	0%	1	0	0.3 file/s/UE
	1 (R1-132890)	random 40% off		0%	9%		3	0	0.4 file/s/UE
High turn-off ratio (50% off)	2 (R1-132933)	random 50% off	15%	19%			1	0	4 file/s/macro, 0.13 file/s/UE
	2 (R1-132933)	random 50% off, (400,200) transition	6%	14%			1	0	4 file/s/macro, 0.13 file/s/UE
	2 (R1-132933)	lowest association 50% off	19%	26%			1	0	4 file/s/macro, 0.13 file/s/UE
	2 (R1-132933)	lowest association 50% off, (400,200) transition	8%	17%			1	0	4 file/s/macro, 0.13 file/s/UE
	4 (R1- 133023)	random 50% off	-11%	-32%	-14%	0%	1	0	5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 50% off	-15%	-39%	-20%	0%	1	6	5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 50% off	-12%	-31%	-23%	0%	1	0	7.5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 50% off	-19%	-37%	-30%	0%	1	6	7.5/s/macro (4 picos/ cluster)
	2 (R1-132933)	random 50% off	11%	10%			1	0	10 file/s/macro, 0.33 file/s/UE
	2 (R1-132933)	random 50% off, (400,200) transition	5%	8%			1	0	10 file/s/macro, 0.33 file/s/UE
	2 (R1-132933)	lowest association 50% off	16%	7%			1	0	10 file/s/macro, 0.33 file/s/UE
	2 (R1-132933)	lowest association 50% off, (400,200) transition	6%	11%			1	0	10 file/s/macro, 0.33 file/s/UE
	4 (R1- 133023)	random 50% off	-13%	-36%	-23%	0%	1	0	10/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 50% off	-21%	-40%	-30%	0%	1	6	10/s/macro (4 picos/ cluster)
	2 (R1-132933)	random 50% off	1%	-17%			1	0	18 file/s/macro, 0.6 file/s/UE
	2 (R1-132933)	random 50% off, (400,200) transition	-1%	-13%			1	0	18 file/s/macro, 0.6 file/s/UE
	2 (R1-132933)	lowest association 50% off	11%	-5%			1	0	18 file/s/macro, 0.6 file/s/UE
	2 (R1-132933)	lowest association 50% off, (400,200) transition	5%	-2%			1	0	18 file/s/macro, 0.6 file/s/UE
Very high turn-off ratio (75% off)	4 (R1- 133023)	random 75% off	-29%	-60%	-45%	-2%	1	0	5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 75% off	-38%	-67%	-55%	-2%	1	6	5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 75% off	-28%	-57%	-41%	0%	1	0	7.5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 75% off	-31%	-62%	-44%	0%	1	6	7.5/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 75% off	-32%	-65%	-50%	-6%	1	0	10/s/macro (4 picos/ cluster)
	4 (R1- 133023)	random 75% off	-41%	-70%	-59%	-10%	1	6	10/s/macro (4 picos/ cluster)

It is observed from the evaluation results that:

- With no MBSFN subframe configured as baseline:
    a. Semi-static on/off based on traffic load can offer moderate gains (mainly concentrated in the range of 5% to 27%) with low/medium small cell turning-off ratio (≤40% off of randomly selected small cells) and with low/medium traffic load.
    b. With high/very high small cell turning-off ratios (≥50% off), the gains are lower or vanish, especially with high traffic load. Loss was observed by some companies.
- With 6 MBSFN subframes configured as baseline:

c. A single contribution provides results for high/very high small cell turning-off ratios (≥50% off) which shows performance loss.

b) Semi-static on/off scheme based on UE-cell association

In this case, a turned-on small cell may be turned off if there is no UE associated to it, and a turned-off small cell may be turned on if the network decides a UE to be associated to it. The UE-cell association may be decided by the network taking into account of UE measurements (e.g. mobility measurements) and load balancing/shifting considerations.

The performance gains for semi-static on/off based on UE-cell association are summarized in Table 7.1.1.1.1-2.

Table 7.1.1.1.1-2 Performance gains for semi-static on/off based on UE-cell association

Scenario	Source	On/off parameters/setting	UPT gains			Assumptions
			Mean UPT	5%ile UPT	50%ile UPT	Traffic load
2a, 10picos/macro	1 (R1-132890)			10%	13%	0.4files/UE, 15UEs/macro
				52%	35%	0.8files/UE, 15UEs/macro
	2 (R1-132933)		13%	23%		4 file/s/macro, 0.13 file/s/UE
			12%	13%		10 file/s/macro, 0.33 file/s/UE
			16%	-4%		18 file/s/macro, 0.6 file/s/UE
		(400,200) transition1	6%	16%		4 file/s/macro, 0.13 file/s/UE
			6%	10%		10 file/s/macro, 0.33 file/s/UE
			9%	-2%		18 file/s/macro, 0.6 file/s/UE
	3 (R1-133324)		5%	5%	12%	0.3 file/s/UE
NOTE: "(400,200) transition" stands for 400ms off-to-on transition time and 200ms on-to-off transition time.						

It is observed from the evaluation results that

- Semi-static on/off based on UE-cell association can offer moderate (~10%) to large (>20%) gains with low/medium traffic load.
- The large gains are observed in cases with sparse UE distributions.
- Note that all results available for this scheme assume no MBSFN subframe configured.

c) Semi-static on/off scheme based on packet call arrival/completion, with transition time modeled

In this case, a turned-off small cell may be turned on if a packet call arrives and needs to be transmitted, and the cell may be turned off after the packet call is completed. An off-to-on transition time and on-to-off transition time are modeled. Various assumptions on small cell and UE capabilities, status, protocols, etc., can affect the feasibility of the considered time scales for on/off transitions.

The performance gains for semi-static on/off based on packet call arrival/completion with transition times are summarized in Table 7.1.1.1.1-3 (for transition time ≤ 100ms) and Table 7.1.1.1.1-4 (for transition time > 100ms). In the tables, "(x,y)" stands for x ms off-to-on transition time and y ms on-to-off transition time.

Table 7.1.1.1.1-3 : Performance gains for semi-static on/off based on packet call arrival/completion, with transition time ≤ 100ms

Scenario	Source	On/off parameters/setting	UPT gains				MBSFN/ABS	RU
			Mean	5%ile	50%ile	95%ile		
2a, 10picos/macro	1 (R1-132890)	(20,20)		42%	48%		0	mean RU for baseline: 13%
		(40,40)		44%	35%			
		(80,50)		28%	10%			
		(20,20)		37%	39%			mean RU for baseline: 32%
		(40,40)		30%	27%			
		(80,50)		21%	8%			
2a,4picos/macro,60UE per Macro area	2(R1-133191)	(50, 50)	21.10%				0	30.0%
2a,4picos/macro	3 (R1-133762)	(15, 0)			19.60%		6 (BCT)	Pico RU for baseline: 25.96%
					24.00%			Pico RU for baseline: 5.8%
					10.50%			Pico RU for baseline: 58.4%
					20.90%			Pico RU for baseline: 21.09%
					20.4%		6 (NCT)	Pico RU for baseline: 25.7%
					24.20%			Pico RU for baseline: 5.68%
					13.20%			Pico RU for baseline: 58.56%
					23.94%			Pico RU for baseline: 21.17%
2a, 10pico	4 (R1-133456)	(40,50)DL based: transmission of DL RS of 10 ms,		40%	35%	14%	6	Mean RU for baseline: 19.5%
		(40,50)DL based: transmission of DL RS of 50 ms,		35%	30%	12%		
		(40,50)DL based: transmission of DRS of 1ms,		42%	44%	14%		
		(40,50)DL based: transmission of DL RS of 10 ms,		36%	21%	13%		Mean RU for baseline: 31.8%
		(40,50)DL based: transmission of DL RS of 50 ms,		33%	17%	8%		
		(40,50)DL based: transmission of DRS of 1ms,		39%	28%	17%		
		(40,50)DL based: transmission of DL RS of 10 ms,		22%	15%	8%		Mean RU for baseline: 47.1%
		(40,50)DL based: transmission of DL RS of 50 ms,		17%	12%	2%		
		(40,50)DL based: transmission of DRS of 1ms,		23%	18%	9%		

It is observed from the evaluation results that, for semi-static on/off based on packet call arrival/completion with transition time lower than 100ms,

- Large (>20%) gains are observed with low/medium traffic load with both 0 and 6 MBSFN subframes configured. The gain is generally larger with shorter off-to-on transition time.
- UPT is calculated including the off-to-on transition time.

Table 7.1.1.1.1-4 Performance gains for semi-static on/off based on packet call arrival/completion, with transition time > 100ms

Scenario	Source	On/off parameters/setting	UPT gains		Assumptions	
			Mean	5%ile	Note	RU
2a,4picos/macro,60UE per Macro area	1(R1-133191)	(400, 400)	12.60%		served time w ithout consideration of off-to-on transition time	30.0%
		(200, 200)	13.90%			
2a, 10picos/macro	2 (R1-133769)	(400,200)	8.5%		served time w ithout consideration of off-to-on transition time	25.0%
		(300,100)	12.60%			
		(250,50)	19.80%			
		(400,200)	6.00%		served time w ithout consideration of off-to-on transition time	75.0%
		(300,100)	7.70%			
		(250,50)	10.50%			
2a, 10picos/macro	3 (R1-132933)	(400, 200)	-18%	-14%		4 file/s/macro, 0.13 file/s/UE
			-20%	-9%		10 file/s/macro, 0.33 file/s/UE
			-21%	-1%		18 file/s/macro, 0.6 file/s/UE
2a, 10picos/macro	4 (R1-133829)	every 200ms periodic ON from OFF, and OFF from ON if no UE is associated	2%	4%		lamda = 10
		(500/50) if SC is OFF, (100,50) if SC is already ON	8.7%	3.3%		lamda = 10 (43%for MRU,11% for SRU)
2a, 10pico	5 (R1-133456)	(240,50)UL based		-13%		Mean RU for baseline: 19.5%
		(240,50)UL based		-10		Mean RU for baseline: 31.8%
		(240,50)UL based		-7		Mean RU for baseline: 47.1%
2a, 4picos/macro	6(R1-133104)	(400,200)*	-18%	-8%		20%
			-13%	-4%		36%
		(400,200)**	-22%	-16%		20%
			-18%	-7%		36%
1, 4picos/macro	(R1-133103)	(400,200)* / NO ABS	-6%	-3%		47%
		(400,200)* / 3 ABS	-7%	4%		34%
		(400,200)** /No ABS	-12%	-8%		47%
		(400,200)** / 3 ABS	-13%	-5%		35%
3, Sparse (2 pico/10Ues per pico), Dense 1(8 pico/5Ues per pico) Dense 2(8pico/10Ues per pico)	(R1-133105)	Sparse (400, 200)*	-17%	-22%		28%
			-10%	-16%		56%
		Dense 1(400, 200)*	-12%	-6%		21%
			-6%	-8%		46%
		Dense 2(400, 200)*	-13%	-6%		15%
			-1%	1%		64%

NOTE *: Considers additional UE connection delay 200ms
NOTE **: Once a cell triggered to be turned off, the cell finishes the turn off procedure regardless of new packet arrival

It is observed from the evaluation results that

- Semi-static on/off based on packet call arrival/completion with transition time larger than 100ms can offer low or no gains. Loss was observed by some companies.
- Note that gains are observed in some sets of results where off-2-on transition time is not included when calculating UPT.

7.1.1.1.2 Ideal, dynamic small cell on/off schemes and performance gains

In these schemes, the small cells may be turned on/off in subframe level, following criteria such as packet arrival/completion and the need for interference coordination/avoidance in subframe time scales. In other words, at the moment of a packet arrival, the small cell can be turned on immediately and transmit the packet to a UE, and it can be turned off at the moment of the completion of the packet. Likewise the small cell can be turned on/off immediately based on the need for interference coordination/avoidance. Clearly, these schemes cannot be supported at least according to current standards, and they are studied in SCE SI to provide performance gain upper bounds for on/off adaptation.

The performance gains for ideal, dynamic on/off based on packet arrival/completion are summarized in Table 7.1.1.1.2-1 (with 0 MBSFN per radio frame and no cell ID planning), Table 7.1.1.1.2-2 (with 0 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster), Table 7.1.1.1.2-3 (with 6 MBSFN per radio frame and no cell ID planning), and Table 7.1.1.1.2-4 (with 6 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster).

Table 7.1.1.1.2-1 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and no cell ID planning

Scenario	Source	UPT gains					
		Mean	5%ile	50%ile	95%ile	Traffic load	RU
1, 4pico	1 (R1-133431)	30%	18%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		30%	32%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
2a, 4pico	1 (R1-133431)	41%	5%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		45%	16%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		52%	44%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	3 (R1- 133023)	23%	13%	35%	2%	5/s/macro	
		22%	10%	26%	0%	7.5/s/macro	
		17%	6%	19%	3%	10/s/macro	
2a, 10pico	1 (R1-133431)	97%	23%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		100%	27%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		108%	44%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	2 (R1-133591)	53%	71%			low	
		44%	75%			medium	
		20%	52%			high	
	6 (R1-132933)	53%	71%			4 file/s/macro, 0.13 file/s/UE	
2a, 10pico	4 (R1-133871)	53%	120%			lambda=2	

It is observed from the evaluation results that

- Ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and no cell ID planning, can offer large (>20%) gains with low/medium traffic loads.
- The gains are lower with high traffic load.

Table 7.1.1.1.2-2 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster

Scenario	Source	UPT gains				Assumptions	
		Mean	5%ile	50%ile	95%ile	Traffic load	RU
1, 4pico	1 (R1-133431)	6%	9%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		6%	9%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
2a, 4pico	1 (R1-133431)	21%	9%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		23%	4%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		22%	18%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
2a, 10pico	1 (R1-133431)	27%	3%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		26%	12%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		29%	18%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%

It is observed from the evaluation results that, for ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster,

- Low (<10%) gains are observed in Scenario 1 with low/medium traffic loads.
- Moderate (10% to ~20%) gains are observed in Scenario 2a with low/medium/high traffic loads.
- The gains are lower than those without cell ID planning indicated in Table 7.1.1.1.2-1.

Table 7.1.1.1.2-3 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and no cell ID planning

Scenario	Source	UPT gains				Assumptions	
		Mean	5%ile	50%ile	95%ile	Traffic load	RU
1, 4pico	1 (R1-133431)	13%	8%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		14%	10%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
2a, 4pico	1 (R1-133431)	13%	7%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		13%	7%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		16%	5%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	2 (R1-133106)		1.7%	1.3%	0.4%	moderate	the highest layer has a RU = 40%
	3 (R1- 133023)	12%	7%	15%	2%	5/s/macro	
		10%	0%	10%	0%	7.5/s/macro	
		8%	0%	8%	2%	10/s/macro	
2a, 10pico	1 (R1-133431)	30%	4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		34%	1%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		36%	-8%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	2 (R1-133106)	5.8%	5.0%	3.4%		moderate	the highest layer has a RU = 40%
	4 (R1- 133782)	0.8%	2.8%	2.2%			~70% RU for macro ~16% for small cell
		2.3%	1.1%	4.8%			~15% for macro ~28% for small cell

It is observed from the evaluation results that, for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and no cell ID planning,

- Moderate (~10%) gains are observed in Scenario 1 with low/medium traffic loads.
- Moderate (~10%) gains are observed in Scenario 2a with 4 small cells per macro and with low/medium/high traffic loads.
- Large variance of gains, from low (<10%) to large (>20%), are observed in Scenario 2a with 10 small cells per macro and with low/medium/high traffic loads.
- The gains are lower compared with those with 0 MBSFN indicated in Table 7.1.1.1.2-1.

Table 7.1.1.1.2-4 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster

Scenario	Source	UPT gains				Assumptions	
		Mean	5%ile	50%ile	95%ile	Traffic load	RU
1, 4pico	1 (R1-133431)	3%	4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		3%	2%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
2a, 4pico	1 (R1-133431)	8%	-4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		7%	-11%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
		6%	-4%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
2a, 10pico	1 (R1-133431)	14%	4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		12%	6%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
		13%	10%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%

It is observed from the evaluation results that, for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster,

- Low (<10%) gains are observed in Scenario 1 with low/medium traffic loads.
- Low (<10%) or no gains are observed in Scenario 2a with 4 small cells per macro and with low/medium/high traffic loads.
- Moderate (~10%) gains are observed in Scenario 2a with 10 small cells per macro and with low/medium/high traffic loads.
- The gains are lower than those with 0 MBSFN and no cell ID planning indicated in Table 7.1.1.1.2-1, lower than those with 0 MBSFN and cell ID planning ensuring aligned small cell CRS within cluster indicated in Table 7.1.1.1.2-2, and lower than those with 6 MBSFN and no cell ID planning indicated in Table 7.1.1.1.2-3.

7.1.1.1.3 NCT with reduced CRS and performance gains

NCT with reduced CRS (NCTCRS) is studied in NCT WI. Small cell on/off developed in SCE can apply to NCT after it is introduced. The performance gains with NCTCRS are summarized in Table 7.1.1.1.3-1 and compared to small cell on/off.

Table 7.1.1.1.3-1 Performance gains with NCT over baseline BCT without on/off

Scenario	Source	On/off parameters/setting	UPT gains				Assumptions	
			Mean	5%ile	50%ile	95%ile	MBSFN (for baseline)	RU
2a,4picos/macro	1 (R1-133106)	S-NCT with NCTCRS		1.0%	0.7%	0.1%	6	40% RU on the small cell layer
2a,10picos/macro				3.8%	3.2%	2.5%		
2a, 10picos/macro	2 (R1-133769)	NCTCRS	21.6%				0	25%
			19.4%				0	75%
2a,10picos/macro	3(R1-132890)	S-NCT with NCTCRS		70%	80%		0	12.6%
				66%	74%		0	32.3%
2a,10picos/macro	4 (R1-133431)	NCTCRS	120%	186%	120%	186%	0	M-RU 20%
			110%	130%	110%	130%	0	M-RU 40%
			111%	179%	111%	179%	0	baseline M-RU 60%
2a,10picos/macro	4 (R1-133431)	NCTCRS	26%	29%	26%	29%	6	M-RU 20%
			31%	27%	31%	27%	6	M-RU 40%
			27%	33%	27%	33%	6	baseline M-RU 60%
2a,4picos/macro	5 (R1-133762)	Comparison between S-NCT versus BCT with on/off			-16.4 to -19.9 %		6	M-RU 20,40, 60%
2a,4picos/macro	6 (R1-132999)	NCTCRS	4.4%	3.5%	6%	0%	6	26.8%
			5.5%	3.4%	9.4%	0%		42.3%
			7.6%	11%	10.9%	0%		60.7%
			18.8%	20.5%	32%	0%	0	28.9%
			21.7%	19.3%	31.6%	0%		47.3%
			21.3%	24.3%	31.3%	1.64%		64.4%

It is observed from the evaluation results that

When comparing NCTCRS and small cell on/off results from the same sources, the following observations can be made:

- The gains of NCTCRS and idealized dynamic small cell on/off are comparable.
- Several companies showed the gain of NCTCRS is higher than the gain of small cell on/off with small (20 to 80 ms) transition time. One company showed the gain of BCT small cell on/off with 15ms transition time has higher gain than that of S-NCT with NCTCRS in the simulation with system information overhead modeled.
- The gain of NCTCRS is higher than the gain of small cell on/off with large transition time.

7.1.1.2 Small cell on/off energy saving

In addition to potential UPT gains, small cell on/off schemes described in section 7.1.1.1 may also provide benefits in terms of energy savings. The upper bound energy saving potential can be roughly evaluated in terms of active subframe ratio, i.e. the ratio of subframes in which at least some PDSCH transmission takes place. The active subframe ratios for small cell layer in Scenario 2a with 4 picos/macro are summarized in Table 7.1.1.2-1 for various small cell on/off schemes described in 7.1.1.1.

Table 7.1.1.2-1 Active subframe ratio for semi-static on/off based on traffic load (Scenario 2a with 4 picos/macro, 0 dB CRE)

Small cell on/off scheme	Source	Active subframe ratio	
		Low load (10 Mbps/cell)	High load (40 Mbps/cell)
Baseline	Source 1(R1-133485)	100 %	100 %
Semi-static on/off (200, 100) transition	Source 1(R1-133485)	28 %	86 %
Semi-static on/off (50, 100) transition	Source 1(R1-133485)	17 %	75 %
Ideal dynamic on /off	Source 1(R1-133485)	12 %	61 %

It is observed from the evaluation results that, significant part of the energy saving potential can be harvested with moderate time-scale of 200 ms off-to-on transition time and 100ms on-to-off transition time. With more dynamic time scale, the active subframe ratio can be reduced further. It should be noted that reduction in active subframe ratio does not directly translate into network energy savings, but factors such as UE capabilities (i.e. presence of UEs not supporting on/off schemes), how dynamically on/off switching is applied, as well as eNodeB implementation aspects affect the achievable energy savings.

In addition to the small cell on/off schemes listed in Table 7.1.1.2-1, long-term on/off schemes studied in RAN3 Energy Saving SI/WI as well as NCT can also reduce active subframe ratio. In an unloaded cell the active subframe ratio with NCT is 20 % when considering PSS/SSS/NCTCRS only. The small cell on/off schemes described in 7.1.1.1 can potentially be applied on an NCT small cell as well to further reduce active subframe ratio.

7.1.1.3 Time scales for on/off transitions

7.1.1.3.1 Feasible time scales based on legacy procedures

Various assumptions on small cell and UE capabilities, status, protocols, etc., can affect the feasible time scales for on/off adaptation. Legacy procedures such as handover, Scell activation/deactivation may be used to connect/disconnect a legacy UE to a cell:

- Utilizing handover procedure: The network may hand over a connected UE into or out of a small cell when it is on. The transitions generally take hundreds of milliseconds to a few seconds. RRC reconfiguration is generally needed.
- Utilizing SCell procedures: The network may activate/deactivate a configured SCell. The transitions generally take tens of milliseconds to hundreds of milliseconds, and RRC reconfiguration is generally not needed. On the other hand, to configure/release a SCell may take hundreds of milliseconds, and RRC reconfiguration is generally needed; however the configuring/releasing a SCell are needed only once in a while.

The feasible time scales based on legacy procedures are summarized in Table 7.1.1.3.1-1.

Table 7.1.1.3.1-1 Small cell on/off time scales based on legacy procedures

Cases	Explanations	Time scales of ON/OFF
1	Time before a UE without CA capability can use a just turned on small cell	2000 to 4000 ms order The major delay is the time to detect new cell by UE inter-frequency measurement.
2	Time before a UE without CA capability can use an already on small cell	100 to 150 ms order
3	Time before a UE with CA capability can use a just turned on small cell as SCell. More than CP length level synchronization between macro and small cell	500 to 1000 ms order The major difference from case 1 is intra-frequency measurement.
4	Time before a UE with CA capability can use an already on small cell as SCell	80 to 120 ms order
5	Time required switching off a cell. All UEs in a small cell were RRC_CONNECTED and no Idle UE present in a cell. All UEs already reported measurement report as the target neighbor cells.	100 to 150 ms order

The order of magnitude of feasible time scales using legacy procedures for small cell on/off mainly depend on UE capability (CA capable or not), UE status (idle, DRX, or continuous RX), and the frequency (inter-frequency or intra-frequency) of the cells. Small cell on/off is feasible at least at the seconds level when legacy mechanisms are used.

The small cell on/off schemes that can be supported by legacy procedures include semi-static on/off based on traffic load, UE association, and/or based on data burst with transition time of a few hundred milliseconds (when all UEs connected to the cell are CA capable) to a few seconds. On the other hand, dynamic small cell on/off at the time scale of subframe level is not backward compatible.

7.1.1.3.2 Feasible time scales enhancements

Faster transitions for small cell on/off have also been discussed, mainly based on discovery enhancement and dual connectivity.

- Utilizing discovery signals. Discovery signals may be sent from a turned-off small cell and UE can perform necessary measurements. The measurements may be utilized so that additional measurement duration after the cell is turned on can be significantly reduced (to, e.g. tens of milliseconds or even shorter).
- Utilizing dual connectivity. Legacy handover procedures may be streamlined under the assumptions such as dual connectivity. Dual connectivity may allow a faster transition by reducing/eliminating the needs for handover to and from a small cell performing on/off. Once dual connectivity between a UE and a small cell is configured, the activation/deactivation of the cell based on a procedure similar to carrier aggregation may be used, and the time scale may be in the tens of milliseconds level or possibly even less.

To summarize, with enhanced procedures based on discovery signals during small cell off and dual connectivity operations, small cell on/off feasible time scales can be reduced to less than 100milliseconds.

7.1.1.4 Potential impacts on network performance other than throughputs

Other potential network impacts may include network coverage, legacy UE support, mobility, and energy consumption.

- Network coverage and idle UE support can be ensured if a coverage layer (e.g. macro layer) exists.
- Mobility: Mobility aspects have not been discussed in RAN1.
- Energy consumption: reduction of energy consumption is expected, see 7.1.1.2.

7.1.1.5 Standards impacts for enhancements

Potential standards impacts for several enhancements of mechanisms and procedures for small cell on/off mainly include:

- Physical signals to assist adaptation, such as DL/UL discovery signals, see 7.2
- Enhanced network load/utilization metrics and exchange, see 7.1.4
- Enhanced procedures for reducing transition feasible time scales, such as simplifying/eliminating handover procedures by utilizing, e.g. dual connectivity, see 7.1.1.3.2.
- Procedures and measurements enhancements for coordinated network decision making

There may also be impacts on other aspects, e.g. CSI feedback.

7.1.2 Enhanced power control/adaptation

This technique is studied for both uplink and downlink transmission.

Small cell downlink power control refers to the adaptation of a small cell (which may also refer to a small cell CC) transmission power, including possibly both the common channel power and data channel power. Downlink power enhancement can be designed in a cell-specific way or a UE-specific way.

Small cell interference mitigation based on downlink power control may be considered with respect to the mobility impact and modification time scale perspective.

Possible uplink power control enhancement may take into account interference generated to non-serving cells. In one considered uplink power control scheme, path losses to multiple points would be considered in determining the uplink transmission power.

7.1.3 Enhancement of frequency domain power control and/or ABS to multi-cell scenarios

An example of the frequency domain power control is eNodeB Relative Narrowband TX Power restrictions (RNTP). The present document should include in this subclause the consideration of ePDCCH.

7.1.3.1 Enhancement of (e)ICIC to multi-cell scenarios for small cell deployments

Since Rel-8/Rel-9, ICIC is a frequency-domain interference coordination scheme to reduce interference between cells in co-channel deployment scenarios by exchanging power restriction (RNTP) at PRB-level. In Rel-10/Rel-11, eICIC is introduced as a time-domain coordination scheme to reduce interference between cells in co-channel deployment scenarios by applying ABS (almost blank subframes) for a dominant interferer. In Rel-12 dense small cell deployment, there may not be a single dominant interference source anymore. Interference between small cells can be significant when the number of deployed small cells increases.

Enhancement of (e)ICIC to multi-cell scenarios has been proposed for small cells deployments, including:

- Time domain interference coordination
  - Different ABS patterns could be configured for different small cells
  - Fast ABS pattern adaptation
  - eNB may apply different downlink power control strategies considering the CRS existence in the data region
- Frequency domain interference coordination
  - Different PRB/CC(s) could be configured for different small cells, including autonomous carrier selection

Supporting the enhancement of (e)ICIC has the following potential specification impacts:

- Study backhaul requirements
  - Define the signalling and time scale to support faster adaptation rate for (e)ICIC
- Design the resource coordination mechanism in the time and frequency domain in a coordinated manner
  - E.g. One aggressor small cell sends ABS allocation of one victim small cell to the other victim small cell
- Support restricted subframe measurement also on SCell
- Enhance CSI measurement to support more interference level
  - E.g. Configure UE with more CSI reporting processes for more than two interference levels

7.1.3.2 Enhancement of EPDCCH for small cell deployments

In Rel-11, enhanced PDCCH (EPDCCH) is introduced to improve the control region ICIC performance in frequency domain. In Rel-12 small cell deployment scenarios, the inter-cell interference could become more severe in dense deployment. Compared to PDSCH, EPDCCH needs to be more robust due to lack of HARQ. Thus protecting EPDCCH PRBs by coordination among cells can be considered to achieve stable and efficient EPDCCH performance.

The identified signalling messages between eNBs to support the inter-cell-interference coordination enhancement for EPDCCH are the followings. One or the combination of the listed inter-cell-interference coordination messages could be conveyed by OAM configuration/DL HII(High interference indication)/enhanced RNTP signalling/Load Indication procedure:

- Exchange between eNBs of resource allocation information of EPDCCH
  - Indication of the PRB resources for EPDCCH transmission
  - Indication of preferred EREG groups for EPDCCH transmission
- Exchange between eNBs of time-domain resource allocation information of EPDCCH
  - Indication of the time instants that are configured for EPDCCH transmission
- Exchange between eNBs of multi-level transmitted power of PRBs
  - Indication of different transmission powers for EPDCCH and PDSCH PRBs
- Exchange between eNBs of multi-level interference preference of PRBs
  - Indicate the interference sensitivity level of the PRBs, which would be useful for other eNBs to perform scheduling with this interference sensitivity of neighbor eNBs
- Exchange between eNBs of a separate set of PRBs used for sensitive data protection (e.g., EPDCCH)
  - Indication of a set of PRBs with low power for a relatively long time
- For any possible further study it is important to consider the tradeoffs of EPDCCH ICIC techniques and overall network spectral efficiency and possible implications on feedback design

7.1.4 Load balancing/shifting

The study for cell association is included in this subclause. Techniques listed here are mentioned purely for information, and no endorsements or recommendations are implied.

The purpose of load shifting/balancing is to improve the overall system performance by changing the traffic load distribution over cells/layers. One intention with the load shifting could be to obtain a more evenly distributed traffic load across the cells/layers. Another intention with the load shifting could be to concentrate the traffic into fewer cells in order to mitigate inter-cell interference in dense small cell deployments.

Load balancing/shifting can be achieved via cell association. Several cell association options have been studied, including:

- Cell association based on RSRP in conjunction with a cell association bias
- Cell association based on RSRQ in conjunction with a cell association bias or threshold
- Cell association based on long-term SINR UE measurements in conjunction with a cell association bias
- Cell association based on a function of UE measurements (RSRP, RSRQ, long-term SINR.) and of network-side information (e.g. cell resource utilizations
- Cell association based on RSRQ or SINR UE measurements within shortened measurement interval

NOTE: A shortened measurement interval may enable faster adaptation to the load change across frequency layers. However, accuracy aspects of RRM measurement would need to be considered when measurement interval is shortened.

Among the considered methods for load balancing/shifting, the following would have specification impacts:

- Long-term SINR UE measurements
- Short-term RSRQ and short-term SINR UE measurements
- Interference measurements on CSI-IM resources for the purpose of RRM
- Backhaul signalling such as resource utilization information exchange to assist load shifting/balancing decision making
- Discovery signal might be designed to assist load shifting/balancing decision making, for example by using a discovery signal as an indicator of load level

7.2 Mechanisms for efficient discovery of small cells and their configurations

Considering small cell deployment scenarios, following issues are foreseen as potential motivations to enhance the small cell discovery mechanism.

- Severe interference among synchronization signals/reference signals of densely deployed small cells
- Larger UE effort on inter-frequency small cell identification in multi-carrier operation scenarios
- Larger cell planning effort to avoid PCI collision and PCI confusion in super-dense deployment
- Necessity of efficient mechanism to support the small cell on/off operation if it is introduced

On top of above issues, to expand the possibilities for efficient operations in small cell layer such as load balancing/shifting, CoMP/ICIC, efficient small cell on/off, and to enhance mobility robustness in the small cell layer, the enhancement of cell detection could be considered for the timely detection of surrounding small cells. In addition, inter-frequency measurement mechanism for small cell discovery could be enhanced to maintain UE energy efficiency and detection/measurement time requirements.

In this section, the discussion is focused on the mechanisms for efficient discovery of small cells, which is a potential technique to ensure efficient operation of a small cell layer composed of small cell clusters.

7.2.1 Performance evaluation

7.2.1.1 Rel-8 mechanism

First, to study whether the legacy cell search mechanism shows sufficient performance or inadequacies in the small cell deployment, evaluations on discovery performance of the Rel-8 mechanism based on PSS/SSS/CRS have been performed with the baseline assumptions shown in Annex A.4.

Evaluation results on the small cell detection performance in SCE scenario 2a with dense deployment for the top three small cells are summarized in Table 7.2-1.

Table 7.2-1 Detection probability performance of Rel-8 mechanism for the top three small cells in scenario 2a, dense deployment (1 cluster/macro, 10 small cells/cluster)

Number of measurement samples for PSS/SSS		Detection probability			Different assumptions from Annex A.4
		1st cell	2nd cell	3rd cell	
1 sample	Source 1	0.87	0.38	0.11	
	Source 2	0.86	0.35	0.10	
	Source 3	0.90	0.32	0.11	
	Source 4	0.96	0.58	0.25	- Frequency offset: 0 Hz - SINR vs Detection probability curve is derived by AWGN channel
	Source 5	0.99	0.55	0.21	- In SINR vs Detection probability curve, number of neighbour small cells explicitly modelled is unclear
	Source 6	0.97 0.99*	0.89 0.95*	0.75 0.88*	- Time/Frequency offsets: Zero - Location of PSS/SSS is known a priori - Low cross-correlation between PSS/SSS sequences is taken into account * False alarm probability: 0.01
	Source 8	0.99 0.99*	0.87 0.95*	0.55 0.74*	* For the cells with SINR > -6dB
	Source 9	0.93	0.30	0.04	
	Source 10	1.00	0.71	0.21	
2 samples	Source 1	0.97	0.52	0.17	
	Source 2	0.94	0.52	0.20	
	Source 6	1.00 1.00*	0.97 0.99*	0.92 0.96*	- Time/Frequency offsets: Zero - Location of PSS/SSS is known a priori - Low cross-correlation between PSS/SSS sequences is taken into account * False alarm probability: 0.01
	Source 9	0.97	0.46	0.11	
	Source 10	1.00	0.80	0.33	
	Source 11	0.95	0.54	0.27	- All links between eNB and UE are explicitly modelled by the practical physical layer signals without any abstraction into the SLS.
4 samples	Source 1	0.98	0.54	0.22	
	Source 2	0.97	0.54	0.18	
	Source 4	0.99	0.81	0.55	- Frequency offset: 0 Hz - SINR vs Detection probability curve is derived by AWGN channel
	Source 9	0.98	0.55	0.14	
	Source 10	1.00	0.89	0.50	
	Source 11	0.96	0.55	0.28	- All links between eNB and UE are explicitly modelled by the practical physical layer signals without any abstraction into the SLS.
8 samples	Source 1	1.00	0.62	0.28	
	Source 2	0.99	0.61	0.20	
	Source 3	0.97	0.50	0.28	
	Source 5	1.00	0.79	0.63	- In SINR vs Detection probability curve, number of neighbour small cells explicitly modelled is unclear
	Source 7	1.00	0.94	0.87	- In SCH SINR calculation, the average correlation between PSS/SSS sequences is taken into account
	Source 11	0.99	0.57	0.28	- All links between eNB and UE are explicitly modelled by the practical physical layer signals without any abstraction into the SLS.

It is observed from the evaluation results on Rel.8 mechanism that

- For the 1st best RSRP small cell, at least, almost all UEs within a cluster area can detect the best RSRP small cell by using 8 PSS/SSS samples.

- The detection probabilities can be improved to a certain extent as the number of measurement samples for PSS/SSS increases.
- Evaluation results differ substantially depending on the evaluation methodologies.

7.2.1.2 PSS/SSS interference canceller-based mechanism

For further improvement of cell detection performance, some companies have evaluated the PSS/SSS interference canceller (SS-IC)-based cell discovery mechanism. Evaluation results on the small cell detection performance in SCE scenario 2a with dense deployment for the top three small cells are summarized in Table 7.2-2.

Table 7.2-2 Detection probability performance of SS-IC-based mechanism for the top three small cells in scenario 2a, dense deployment (1 cluster/macro, 10 small cells/cluster)

<table>
<tr><th rowspan="2">Number of measurement samples for PSS/SSS</th><th rowspan="2"></th><th colspan="3">Detection probability</th><th rowspan="2">Different assumptions from Annex A.4</th></tr>
<tr><th>1st cell</th><th>2nd cell</th><th>3rd cell</th></tr>
<tr><td rowspan="3">1 sample</td><td>Source 1</td><td>0.86
0.86*</td><td>0.72
0.72*</td><td>0.31
0.45*</td><td>- 1 SS-IC
* 2 SS-IC</td></tr>
<tr><td>Source 2</td><td>1.00</td><td>0.97</td><td>0.62</td><td>- 2 SS-IC</td></tr>
<tr><td>Source 4</td><td>0.99</td><td>0.98</td><td>0.93</td><td>- SS-IC (multiple interferers are cancelled)
- CDF of number of detected cells is used to derive detection probabilities for top three small cells
- False alarm probability: 0.01
- Time/Frequency offsets: Zero</td></tr>
<tr><td rowspan="2">2 samples</td><td>Source 1</td><td>0.94
0.94*</td><td>0.89
0.89*</td><td>0.50
0.71*</td><td>- 1 SS-IC
* 2 SS-IC</td></tr>
<tr><td>Source 2</td><td>1.00</td><td>0.97</td><td>0.66</td><td>- 2 SS-IC</td></tr>
<tr><td rowspan="2">4 samples</td><td>Source 1</td><td>0.97
0.97*</td><td>0.93
0.93*</td><td>0.52
0.77*</td><td>- 1 SS-IC
* 2 SS-IC</td></tr>
<tr><td>Source 2</td><td>1.00</td><td>0.98</td><td>0.78</td><td>- 2 SS-IC</td></tr>
<tr><td rowspan="2">8 samples</td><td>Source 1</td><td>0.99
0.99*</td><td>0.98
0.98*</td><td>0.62
0.84*</td><td>- 1 SS-IC
* 2 SS-IC</td></tr>
<tr><td>Source 3</td><td>0.99</td><td>0.96</td><td>0.96</td><td>- 2 SS-IC
- All links between eNB and UE are explicitly modelled by the practical physical layer signals without any abstraction into the SLS.</td></tr>
</table>

It is observed from the evaluation results on SS-IC-based mechanism that

- The detection probabilities for the 2nd and 3rd best RSRP small cells can be improved significantly.
- For the 3rd best RSRP small cell, some results (Sources 1 and 2) show that the detection probability is significantly lower than those for the 1st and 2nd best RSRP small cells especially the case of using only 1 PSS/SSS measurement sample; another result (Source 4) shows that the detection probability is virtually the same as for the 1st and 2nd best RSRP cell.

7.2.1.3 Other RS-based mechanisms (with existing RS)

For further improvement of cell detection performance, some companies have investigated the new cell discovery mechanism based on existing RS such as PRS and CSI-RS.

Compared to PSS and SSS, PRS and CSI-RS have longer transmission periods in general. To avoid the large UE effort on the timing search, it could be considered that the eNB informs RRC_CONNECTED UE the rough timing of RSs for the small cell discovery so that the UE can detect PRS or CSI-RS without the large effort on the timing search.

Evaluation results on the small cell detection performance in SCE scenario 2a with dense deployment for the top three small cells are summarized in Table 7.2-3.

Table 7.2-3 Detection probability performance of the existing RS-based mechanisms for the top three small cells in scenario 2a, dense deployment (1 cluster/macro, 10 small cells/cluster)

Number of Measurement samples for PRS or CSI-RS		Detection probability			Different assumptions from Annex A.4
		1st cell	2nd cell	3rd cell	
1 sample	Source 1	1.00	0.99	0.98	- 1 CSI-RS configuration of 2 antenna ports is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured - 50 RBs are used for CSI-RS - Assuming +/- 3 microsecond search window
	Source 2	1.00	0.92	0.72	- PRS of 1 antenna port is transmitted from each cell - 50 RBs are used for PRS - Assuming +/- 3 microsecond search window
	Source 3	1.00	1.00	0.98	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured - 50 RBs are used for CSI-RS - Frequency offset: 0 Hz - SINR vs Detection probability curve is derived by AWGN channel - Assuming perfect timing synchronization
	Source 4	0.98	0.97	0.97	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured -25 RBs are used for CSI-RS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window
	Source 5	0.99	0.87	0.75	- PRS of 1 antenna port is transmitted from each cell - 25 RBs are used for PRS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window
	Source 6	0.99	0.98	0.96	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured - 50 RBs are used for CSI-RS - Time/Frequency offsets: Zero - Assuming perfect timing synchronization

3 samples	Source 4	0.98	0.97	0.96	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured -25 RBs are used for CSI-RS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window
	Source 5	0.99	0.88	0.75	- PRS of 1 antenna port is transmitted from each cell - 25 RBs are used for PRS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window
4 samples	Source 3	1.00	1.00	0.99	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured - Frequency offset: 0 Hz - SINR vs Detection probability curve is derived by AWGN channel - Assuming perfect timing synchronization
5 samples	Source 4	0.98	0.98	0.97	- 1 CSI-RS configuration of 1 antenna port is assigned to each cell - For other CSI-RS configurations, ZP-CSI-RS is configured -25 RBs are used for CSI-RS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window
	Source 5	0.99	0.88	0.76	- PRS of 1 antenna port is transmitted from each cell - 25 RBs are used for PRS - Maximum timing offset: 0.1 CP - Maximum frequency offset: 1.875 kHz - Assuming +/- 0.1 CP search window

It is observed from the evaluation results on the new mechanism based on existing RS that

- The detection probabilities for top three small cells can be improved significantly even if only 1 measurement sample is applied for the small cell discovery.
- The muting mechanism such as ZP-CSI-RS can provide significant performance improvement, when the appropriate muting pattern is assigned to small cells within the same cluster.

7.2.2 Enhancements of small cell discovery

The following enhancements have been studied for achieving the benefits for the small cell discovery.

7.2.2.1 PSS/SSS interference cancellation

UE PSS/SSS IC can be utilized to enhance the performance of small cell discovery, i.e., more small cells can be detected by removing the effects of interference. It may not require a new standardised procedure and can be achieved by defining new UE performance requirements.

7.2.2.2 Burst transmission of DL-SS/RS

If small cell on/off mechanisms are supported (cf section 7.1.1), a small cell in dormant state or DTX state transmits a DL-SS/RS burst with low duty cycle.

- As a DL-SS/RS burst, PSS/SSS/CRS, CSI-RS, PRS, modified SS/RS or new discovery signal can be considered.
- At least, the legacy PSS/SSS/CRS can be transmitted from a small cell in active state as usual so that the legacy UE can detect and measure the active small cell.

Following benefits may be achieved by this solution.

- For the DL-based small cell on/off mechanisms, a DL-SS/RS burst with long duty cycle may be transmitted by small cells in dormant state or DTX state so that the network would be able to make a quick decision on whether to activate the eNB or not based on the measurement report from RRC_CONNECTED UEs
- A DL-SS/RS burst with long duty cycle can also provide additional help for UL-based small cell on/off mechanisms for small cells in dormant state or DTX state so that the network would be able to make a quick decision on whether to activate the eNB or not based on the measurement report from RRC_CONNECTED UEs.
- For enabling small cell on/off (e.g., in absence of macro coverage), a DL-SS/RS burst with low duty cycle may be transmitted by small cells in dormant state so that an Idle UE would be able to know the cell may be available for connection later.

7.2.2.3 Network synchronization and assistance

An eNB informs an RRC_CONNECTED UE the rough timing of the cluster so that the UE can reduce the effort on cell detection, especially in the case of synchronized transmission of SS/RS from small cells within the same cluster.

Although the synchronized transmission of SS/RS among small cells causes severe interference regardless of the amount of traffic load, it can provide several benefits as follows.

- It can minimize the search window at UE by using network assistance, i.e., rough timing information of the synchronized transmission of SS/RS, so that the UE effort on small cell discovery is reduced.
- It can maximize the detection performance gain of PSS/SSS-interference canceller, i.e., accurate cancellation based on synchronization and efficient interference mitigation among SS/RS signals.

In addition, an eNB may inform an RRC_CONNECTED UE the PCI-like information and/or RS configuration information of candidate small cells in addition to the timing information so that the UE can effectively detect SS/RS of multiple small cells at the same time. This type of network assistance can also be applied on top of the current cell detection mechanisms (i.e. PSS/SSS).

7.2.2.4 New discovery mechanism

Following potential solutions to enhance the cell detection performance can be considered if enhancement of cell detection performance is necessary.

- Solution 1: Existing RS-based detection
    - Small cells at least within the same cluster transmit legacy PRS or CSI-RS with a coordination to avoid the collision between selected configurations.
    - Different nodes may need to inform each other about the selected configuration of PRS or CSI-RS.

  - If small cell on/off mechanisms are supported (cf section 7.1.1), small cells in active/dormant state transmit legacy PRS or CSI-RS burst with low duty cycle in addition to PSS/SSS/CRS in active state. Both active/dormant small cells within the same cluster synchronously transmit PRS or CSI-RS burst.
  - For this solution, a modification of any RS may not be necessary. New detection and measurement mechanisms based on PRS or CSI-RS should be specified. New measurement mechanisms may require RE muting pattern modifications.
- Solution 2: Modified SS/RS or new discovery signal-based detection
  - The eNB may inform an RRC_CONNECTED UE the configuration information of modified SS/RS or discovery signal in addition to the timing information so that the UE can effectively detect modified SS/RS or discovery signal of multiple small cells at the same time.
  - If small cell on/off mechanisms are supported (cf section 7.1.1), small cells in active/dormant state transmit modified SS/RS or new discovery signal with low density allocation of time/frequency resource in addition to PSS/SSS/CRS in active state.
  - The impact on legacy UEs, the increase of overhead, and the specification impact should be considered together with the achievable gain of this solution.
  - The impact on idle UEs in terms of cell detection and related power consumption would need further investigations.
  - Potential approaches include PSS/SSS muting, PSS/SSS sharing, double PSS/SSS, resource extension/densification, using the unused REs next to the legacy SS/RS, RE muting, and new discovery signal design.

Following benefits may be achieved by these solutions.

- Allowing for robust detection/measurement performance even with synchronized transmission of DL-SS/RS within a single subframe, leading to more efficient inter-frequency measurement and robust intra-frequency mobility.
- Since these solutions potentially achieves accurate detection of many surrounding small cells, various efficient operations in the small cell layer such as load balancing/shifting, CoMP/ICIC and efficient small cell on/off can be realized.

7.2.2.5 Transmission of DL-SS/RS at specific carrier

If small cells operating at different carrier frequencies transmit DL-SS/RS at a specific carrier frequency (e.g., one of the multiple small cell carriers or the macro cell carrier), the UE effort for inter-frequency small cell discovery may be relaxed.

7.2.2.6 Relaxed RAN4 requirement

Relaxed RAN4 requirement can reduce the detection time at UE, but it increases the detectable SINR target. This solution has been discussed in RAN2 WI of Mobility enhancements in heterogeneous networks.

7.2.2.7 Specification impacts

Supporting the efficient discovery mechanism based on some or all of above solutions has the following potential specification impacts:

- A DL-SS/RS burst transmission configuration for small cell on/off, e.g., new transmission period and duration of DL-SS/RS, if small cell on/off mechanisms are supported (cf section 7.1.1) and if network assistance to be introduced.
- RRM measurement requirement and procedure considering the synchronized transmission of DL-SS/RSs and the network assistance (if it is introduced)
- RRM measurement requirement and procedure considering the small cell on/off operation (if it is introduced)
- Mechanism for the network assistance (if it is introduced)
- For the solution 2 in section 7.2.2.4, the design of DL-SS/RS for small cell discovery (if it is introduced)
- RAN4 requirement for UE SS/RS-IC (if it is introduced)

7.2.3 Necessity of PCI extension

Larger cell planning effort to avoid PCI collision and PCI confusion in dense deployments is seen as a potential motivation to enhance the small cell discovery mechanism.

Evaluation results regarding the PCI collision problem are summarized in Table 7.2-4.

Table 7.2-4 Probability of PCI collision

	PCI collision threshold (note)		
	X=10 dB	X=15 dB	X=20 dB
Source 1 (504 PCIs, 500 SCs/macro, uniform distribution)	0.007	0.012	0.017
Source 2 (504 PCIs, 40 SCs/macro in 4 clusters)	0.006	-	-
NOTE: PCI collision is occurring if UE receives a neighbour cell DL signal with the same PCI as serving cell within X dB difference compared to the serving cell DL signal			

It is observed from the evaluation results that in terms of PCI collision, assuming a completely random PCI allocation, the probability of PCI collision is less than 2%.

For PCI confusion, the existing mechanism of reading the Cell Global Identifier from SIB1 utilizing autonomous gaps is deemed sufficient. However, it was also observed that SI reading may become more frequent in dense small cell scenarios.

As a conclusion, the existing cell discovery signals are sufficient in terms of number of individually identifiable cells. However, if standardization of new discovery signals is considered necessary for other reasons, the number of individually identifiable cells may be considered in the design.

7.2.4 Summary on small cell discovery

As a conclusion, enhancement of small cell discovery would be beneficial at least when small cell on/off is supported. In addition, fast and efficient discovery of small cells provides benefits for inter-frequency measurement.

Efficient small cell discovery procedures can be achieved by enhancing the transmission and/or reception of existing SS/RS, including that of PSS/SSS/CRS, CSI-RS, and PRS.

7.3 Feasibility and benefits of radio-interface based synchronization mechanisms

It is well known that TDD system needs inter-cell synchronization on the same frequency or different frequencies within the same band; in addition, for both TDD and FDD, it would be essential to consider the synchronization mechanisms between cells to bring benefit to the existing features (e.g. (f)eICIC, CoMP as well as carrier aggregation) and some potential techniques for small cell enhancements (e.g. efficient small cell discovery). For some other techniques such as advanced receiver at UE, a synchronized network is beneficial for the receiver performance. It is thus observed that

Synchronization for both TDD and FDD systems needs to be considered.

Synchronization by GNSS or synchronization over backhaul network is not always available for small cell deployments, e.g. indoor deployment, hotspots with high buildings around. The additional cost brought by these two mechanisms is also of concern, especially for small cells. Therefore it is beneficial to have a radio-interface based synchronization mechanism when GNSS or backhaul based synchronization are unavailable.

In small cell SI, the study on inter-cell synchronization focuses on the following cases, with non-ideal backhaul on all interfaces

- Synchronization between a small cell and the overlaid macro cell
- Synchronization between small cells in the same cluster
- Synchronization between small cell clusters

The target synchronization accuracy for the purpose of the study was <=3µs. Whether and how the propagation delay between the source cell and the target cell is considered in this target accuracy has not been fully discussed in RAN1.

- The value is used to guide the study. It is not intended to impact any requirement discussion in RAN4.

Certain features, e.g., CoMP, (F)eICIC and eMBMS, have more restrictive synchronization requirements. This necessitates mechanisms satisfying the 3us accuracy target, to have a stricter accuracy requirement, with joint tradeoff consideration of other design aspects. Therefore within the candidate schemes satisfying the 3us accuracy target, the mechanism that can meet stricter accuracy requirement is preferred, with joint tradeoff consideration of other design aspects.

In the following, further investigation on the radio-interface based synchronization solutions (e.g. network listening, UE assisted synchronization) is discussed. Network listening based on signals in current air interface standards is the baseline for this study; any new technique should offer significant advantage compared to the baseline

For convenience, a cell providing synchronization for another cell is defined as a source cell and a cell acquiring synchronization from another cell is defined as a target cell. Note that there could be multiple source cells within a small cell cluster. For the case where not all the target cells can acquire the synchronization from the same source cell in a cell cluster, multi-hop synchronization is needed.

Further study on the solutions of radio-interface based synchronization includes

- Achievable synchronization accuracy
- Resource overhead
- Applicability/compatibility with the ongoing studies
- Cost/complexity of eNBs and UEs
- Standard impacts

7.3.1 Network listening

7.3.1.1 Introduction of network listening

The target cell monitors the network listening RS (e.g, CRS, CSI-RS and PRS) of the source cell directly to maintain synchronization with the source cell. One example is shown in Figure 7-1.When the target cell monitors the source cell, the target cell mutes its own transmission at least when the target cell and the source cell are in the same frequency.

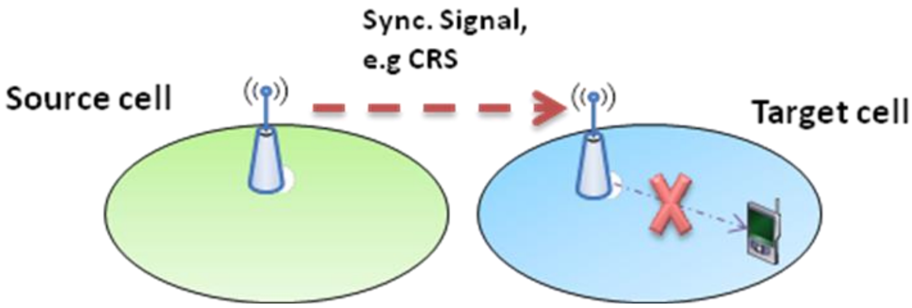


Figure 7-1: Network listening synchronization mechanism

7.3.1.2 Review of the standard work of network listening schemes

Network listening for Home eNodeB synchronization was discussed in the work item of "LTE TDD Home eNodeB RF Requirements" led by RAN4, a technical report [6] was endorsed to capture the related discussion.

It was clarified by RAN4 that

- The synchronization schemes captured in the technical report [6] are aimed to Home eNodeB scenario and for other scenarios these schemes have not been investigated.
- Following the TR, RAN4 has requested RAN3 to introduce some signalling to indicate the stratum level and synchronization status for backhaul signalling mechanism.
- One more point specified is the synchronization accuracy requirement for TDD HeNB. Although some of the synchronization schemes have been studied in RAN4, whether these schemes could meet the synchronization accuracy requirement have not been fully evaluated.

It was clarified by RAN3 that there is no distinction between TDD and FDD in specification for the S1 interface which carries the signalling messages for network synchronization.

7.3.1.3 Achievable synchronization accuracy

The achievable time synchronization accuracy can be impacted by many factors, including

- Channel condition of received network listening RS at the target cell;
  - o High interference in dense small cell deployment may degrade the hearability of the received network listening RS when cells with relatively lower received power must be used for synchronization due to hop number constraints. In such a case, interference management, e.g., by PDSCH-RE-muting to the network listening RS, by SFN transmission of the network listening RS etc. may improve performance in cases where interference is the main limitation. In some cases, increasing the listening period may also improve performance.
- The RS being used for synchronization, e.g., PRS and CRS may have different processing gains and experience different levels of interference;
- Propagation delay between source cell and target cell;
- The number of hops in small cell clusters;
  - o The synchronization accuracy can decrease as the number of hops increases. So the number of maximum hops may have to be limited.
  - o Limiting the number of maximum hops would further decrease the channel condition of received network listening RS at some target cells.
- Time drift between the network listening slots caused by frequency synchronization error

If non-radio interface based solutions cannot always be used for frequency synchronization in small cell deployments, the radio interface based frequency synchronization needs also to be considered. Generally, the radio interface based frequency synchronization is more sensitive to the channel condition of the received network listening RS at the target cell than the radio interface based time synchronization is.

7.3.1.4 Network listening period configuration

In the network listening period when a target cell monitors the source cell, the target cell would stop the DL transmission to its own UEs at least when the target cell and the source cell are in the same frequency. For legacy UEs, the network listening period can be configured in MBSFN subframes, or configured in the GP (Guard Period) in TDD system [6].

For initial acquisition and/or during off periods when the source cell is available, the target cell may use larger listening periods in order to reduce synchronization errors.

It is observed that MBSFN subframes cannot be configured if TDD UL-DL configuration 0 is configured.

It is observed that the maximum stratum level is limited to 2 if GP is used for network listening. [6]

7.3.1.5 Resource overhead

In the network listening periods, if the target cell stops the transmission to its own UEs, the occurrence of the network listening periods brings overhead to the system. Consequently, it is desirable to reduce the overhead. One method is to prolong the detection interval of network listening. As an example, the detection interval is considered to be in the level of seconds. It could be considered to allow the eNB to choose proper detection interval. For example, the eNBs with better clock stability can use a longer interval.

7.3.1.6 Applicability/compatibility with the ongoing studies

Applicability/compatibility of synchronization approaches with other ongoing studies need to be considered. Depending on their detailed design, the ongoing studies to be considered may include NCT, small cell on/off and eIMTA.

7.3.1.7 Support of inter-operator synchronization

Contiguous TDD spectrum allocation among different operators is available and can be more popular in the higher frequency bands. Synchronization becomes important among the cells of different TDD operators deployed in the same band and same region, since the unsynchronized network will incur significant mutual interference and degrade the network performance of both sides, e.g., when the transmit powers on the uplink and downlink are very different. In case that the operators negotiate or exchange information about their common/reference timing, inter-operator synchronization may be achieved by appropriate synchronization requirements in RAN4.

Possible air-interface based approach considered to achieve inter-operator synchronization:

Mutual network listening - With this approach, communication between the cells of different operators is needed, such as the stratum level indication, RS configuration and etc.

7.3.1.8 Cost and complexity

With network listening, an additional receiver is needed at least for the FDD eNB. An additional receiver in the baseband may also be needed for the TDD eNB. There is no additional UE complexity needed for network listening.

7.3.1.9 Standards impacts

To support network listening in small cell scenarios, the potential standards impacts include

- The indication of the synchronization stratum level
- The maximum supported hop number
- Improvement on the achievable synchronization accuracy by improving the channel condition of received network listening RS at the target cells
- Mechanisms to reduce the resource overhead for network listening
- Applicability/compatibility of synchronization approaches with other ongoing studies
- Mechanisms to facilitate inter-operator synchronization

7.3.2 UE-assisted synchronization

The synchronization between the source cell and the target cell can be achieved by some information provided by or obtained from UEs.

The indication of stratum level is also needed when UE-assisted synchronization is applied.

It is observed that the availability and selection of the UEs to assist synchronization may impact the performance of the synchronization.

7.3.2.1 Achievable synchronization accuracy

The achievable synchronization accuracy can be impacted by multiple factors, including

- Availability of UEs
- Channel condition of the received signals at the selected UE side in the downlink, or at the eNB side in the uplink
- The propagation delay difference between the source cell and the target cell at the UE side
    - o Compensation of the propagation delay can be considered.
- The time drift between measurements caused by frequency synchronization error

7.3.2.2 Resource overhead

The resource overhead may include DL resource for triggering UE action, UL resource for UEs to provide information or signal, backhaul resource between source cell and target cell to exchange information etc.

7.3.2.3 Applicability/compatibility with the ongoing studies

Applicability/compatibility of synchronization approaches with other ongoing studies need to be considered. Depending on their detailed design, the ongoing studies to be considered may include NCT, small cell on/off and eIMTA.

7.3.2.4 Support of inter-operator synchronization

It is difficult for a UE to access the network of another operator. With UE-assisted synchronization, inter-operator synchronization may be achieved by appropriate synchronization requirements in RAN4, in case that the operators negotiate or exchange information about their common/reference timing, as discussed in 7.3.1.7.

7.3.2.5 Standards impacts

To support UE-assisted synchronization, the potential standards impacts include

- Mechanisms of UE-assisted synchronization for
    - o UEs to provide information to the network or transmit uplink signals for network to detect
    - o eNBs to exchange information and for the target cell to adjust its timing
    - o Possible measurements on UE and eNB sides including the propagation delays between the UE and both eNBs
- The indication of the synchronization stratum level
- The maximum supported hop number
- Applicability/compatibility of synchronization approaches with other ongoing studies
- Mechanisms to facilitate inter-operator synchronization

7.3.3 Summary

It is beneficial to support radio-interface based synchronization for cases when other methods such as GNSS or synchronization over backhaul are not available. Two solutions are considered, network listening and UE-assisted synchronization.

Both solutions have the following potential standards impacts:

- The indication of the synchronization stratum level
- The maximum supported hop number
- Applicability/compatibility of synchronization approaches with other ongoing studies

To support network listening in small cell deployments, at least the following potential standards impacts need to be considered:

- Improvement on the achievable synchronization accuracy by improving the herability channel condition of received network listening RS at the target cells
- Mechanisms to reduce the resource overhead for network listening

To support UE-assisted synchronization, at least the following potential standards impacts need to be considered:

- Mechanisms of UE-assisted synchronization
    - UEs provide information to the network or transmit uplink signals for network to detect
    - eNBs exchange information and the target cell adjusts its timing
    - Possible measurements on UE and eNB sides including the propagation delays between the UE and both eNBs

For the deployment among the cells of different TDD operators deployed in the same band and same region, mechanisms to facilitate inter-operator synchronization should be considered.

8 Physical layer study for small cell enhancements higher-layer aspects

The definition and applicable scenarios for dual connectivity deployments are described in 0. In this section we describe the foreseen physical layer impacts of dual connectivity.

From PHY layer point of view, a dual-connectivity-capable UE should be able to directly transmit and receive signal to/from both MeNB and SeNB, either simultaneously or in other manners. Depending on the detailed architecture, dual connectivity may have impacts on the following aspects of L1 operation. Details of these impacts would depend on factors such as:

- whether the UE has the capability for simultaneous transmission
- the level of synchronisation and coordination between eNBs

Possible areas of L1 impact include:

- For any UE supporting dual connectivity:
    - Support of separate UCI (e.g., carrying ACK/NACK and CSI feedback, etc) transmission for MeNB and SeNB cells.
        - How to handle SR needs to be further studied
    - Support of independent configurations for UL channels and signals (e.g., PUSCH, PUCCH, DM RS, SRS, etc) toward MeNB and SeNBs
    - If other mechanisms for handling of random access procedure, system information and/or paging reception other than what is supported for CA needs to be defined, e.g. possible support of monitoring CSS in a SeNB cell.
    - If any additional power control function including PHR other than what is used for CA (e.g. separate closed-loop and open-loop) needs to be supported.
- In addition, for a UE with the capability of multiple downlink/multiple uplink reception/transmission in one subframe
    - If any additional power control setting/scaling including PHR and prioritization between UL channels targeting different cells other than what is supported for CA needs to be supported.
    - If UEs need to support wider range of time difference between TAGs, other than what is supported for CA.
    - If it is needed to support UEs without simultaneous PUCCH/PUS(C)CH capability
- In addition, at least for a UE with the capability of multiple downlink reception and single uplink transmission in one subframe,
    - The design may impact UCI transmission mechanisms and timing, resource allocation of UCI, RF retuning gap, UE behavior when UL channel interaction occurs. Potential solutions of single Tx UEs (if supported) for further consideration may include but are not limited to:

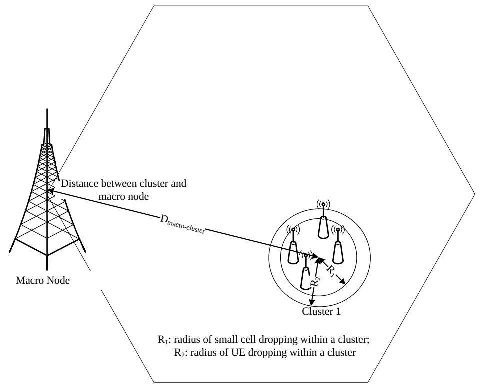
      a) UCI for an eNB is transmitted in an UL resource of the eNB in a TDM fashion between eNBs.

      b) UCI for both eNBs is transmitted in an UL resource of one eNB.

Annex A: Simulation model

A.1 General evaluation assumptions

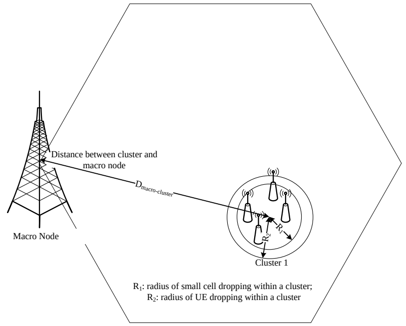
A.1.1 Scenario 1

	Macro cell	Small cell
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 Clusters uniformly random within macro geographical area; small cells uniformly random dropping within cluster area
System bandwidth per carrier	10MHz	10MHz
Carrier frequency	2.0GHz	2.0GHz
Carrier number	1	1
Total BS TX power (Ptotal per carrier)	46dBm	30 dBm, Optional: 24dBm, 37dBm
Distance-dependent path loss	ITU UMa[referring to Table B.1.2.1-1 in TR36.814], with 3D distance between an eNB and a UE applied. Working assumption is that 3D distance is also used for: break point distance LOS probability	ITU Umi [referring to Table B.1.2.1-1 in TR36.814] with 3D distance between an eNB and a UE applied Working assumption is that 3D distance is also used for: break point distance LOS probability

Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,UE-to-eNB distance)] for each link)
Shadowing	ITU UMa according to Table A.1-1 of 36.819 Working assumption is that 3D distance is used for shadowing correlation distance	ITU UMi[referring to Table B.1.2.1-4 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	3D, referring to TR36.819	2D Omni-directional is baseline; directional antenna is not precluded
Antenna Height:	25m	10m
UE antenna Height	1.5m	
Antenna gain + connector loss	17 dBi	5 dBi
Antenna gain of UE	0 dBi	
Fast fading channel between eNB and UE	ITU UMa according to Table A.1-1 of 36.819	ITU Umi
Antenna configuration	2Tx2Rx in DL, Cross-polarized	
Number of clusters/buildings per macro cell geographical area	1, 2, optional of 4	
Number of small cells per cluster	4, 10	
Number of small cells per Macro cell	[4,10]*Number of clusters per macro cell geographical area	
Number of UEs	60 UEs per macro cell geographical area are recommended when FTP model 3 is used	
UE dropping	Baseline: 2/3 UEs randomly and uniformly dropped within the clusters, 1/3 UEs randomly and uniformly dropped throughout the macro geographical area. 20% UEs are outdoor and 80% UEs are indoor.	
Radius for small cell dropping in a cluster	50m	
Radius for UE dropping in a cluster	70m	
Minimum distance (2D distance)	Small cell-small cell: 20m	
	Small cell-UE: 5m	
	Macro –small cell cluster center: 105m	
	Macro – UE : 35m	
	cluster center-cluster center: 2*Radius for small cell dropping in a cluster	
Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.	
UE receiver	MMSE-IRC as baseline	
UE noise figure	9dB	
UE speed	3km/h	
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.	

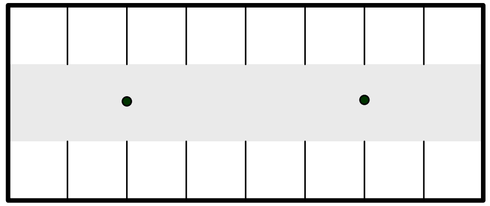
Network synchronization	Baseline is synchronized; if an evaluated feature requires synchronization, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms, 10ms, 50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

A.1.2 Scenario 2a

	Macro cell	Small cell
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 Clusters uniformly random within macro geographical area; small cells uniformly random dropping within cluster area
System bandwidth per carrier	10MHz	10MHz
Carrier frequency	2.0GHz	3.5GHz
Carrier number	1	1 or 2
Total BS TX power (Ptotal per carrier)	46dBm	30 dBm, Optional: 24dBm, 37dBm
Distance-dependent path loss	ITU UMa[referring to Table B.1.2.1-1 in TR36.814], with 3D distance between an eNB and a UE applied Working assumption is that 3D distance is also used for: break point distance LOS probability	ITU Umi [referring to Table B.1.2.1-4 in TR36.814] with 3D distance between an eNB and a UE applied Working assumption is that 3D distance is also used for: break point distance LOS probability
Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	For outdoor UEs:0dB For indoor UEs: 23dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,UE-to-eNB distance)] for each link)
Shadowing	ITU UMa according to Table A.1-1 of 36.819 Working assumption is that 3D distance is used for shadowing correlation distance	ITU UMi[referring to Table B.1.2.1-1 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	3D, referring to TR36.819	2D Omni-directional is baseline; directional antenna is not precluded
Antenna Height:	25m	10m
UE antenna Height	1.5m	
Antenna gain + connector loss	17 dBi	5 dBi
Antenna gain of UE	0 dBi	
Fast fading channel between eNB and UE	ITU UMa according to Table A.1-1 of 36.819	ITU Umi
Antenna configuration	2Tx2Rx in DL, Cross-polarized	

Number of clusters/buildings per macro cell geographical area	1, 2, optional of 4
Number of small cells per cluster	4, 10
Number of small cells per Macro cell	[4,10]*Number of clusters per macro cell geographical area
Number of UEs	60 UEs per macro cell geographical area are recommended when FTP model 3 is used
UE dropping	Baseline: 2/3 UEs randomly and uniformly dropped within the clusters, 1/3 UEs randomly and uniformly dropped throughout the m acro geographical area. 20% UEs are outdoor and 80% UEs are indoor.
Radius for small cell dropping in a cluster	50m
Radius for UE dropping in a cluster	70m
Minimum distance (2D distance)	Small cell-small cell: 20m Small cell-UE: 5m Macro –small cell cluster center: 105m Macro – UE : 35m cluster center-cluster center: 2*Radius for small cell dropping in a cluster
Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.
UE receiver	MMSE-IRC as baseline
UE noise figure	9dB
UE speed	3km/h
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.
Network synchronization	Baseline is synchronized; if an evaluated feature requires synchronisation, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms,10ms,50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

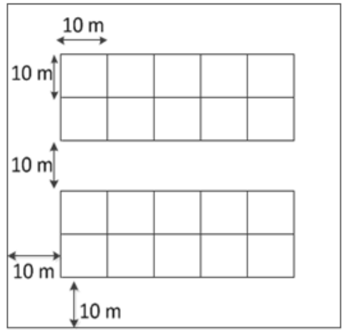
A.1.3 Scenario 2b (sparse)

	Macro cell	Small cell
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 The outdoor clusters in Scenario #2a is replaced by the ITU Indoor Hotspots, the hotspots are uniformly random within macro geographical area. The detailed parameters setting for an indoor hotspot can refer to A.2.1.1.5 in TR36.814.
System bandwidth per carrier	10MHz	10MHz
Carrier frequency	2.0GHz	3.5GHz
Carrier number	1	1
Total BS TX power (Ptotal per carrier)	46dBm	24dBm
Distance-dependent path loss	ITU UMa[referring to Table B.1.2.1-1 in TR36.814], with 3D distance between an eNB and a UE applied Working assumption is that 3D distance is also used for: break point distance LOS probability	For indoor UEs in the same building: ITU InH [referring to Table B.1.2.1-1 in TR36.814] For outdoor UEs and indoor UEs in another building, working assumption is ITU UMi [referring to Table B.1.2.1-1 in TR36.814] 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability
Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	For indoor UEs in the same building: 0dB For outdoor UEs: 23dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,UE-to-eNB distance)] for each link) For indoor UEs in another building: 46 dB+0.5(d_{in_1}+ d_{in_2}) (d_{in_1} and d_{in_2} are independent uniform random value between[0, min(25,UE-to-eNB distance)] for each link)
Shadowing	ITU UMa according to Table A.1-1 of 36.819 Working assumption is that 3D distance is used for shadowing correlation distance	ITU InH [referring to Table A.2.1.1.5-1 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	3D, referring to TR36.819	2D Omni-directional is baseline; directional antenna is not precluded

Antenna Height:	25m	6m
UE antenna Height	1.5m	
Antenna gain + connector loss	17 dBi	5dBi
Antenna gain of UE	0 dBi	
Fast fading channel between eNB and UE	ITU UMa according to Table A.1-1 of 36.819	For indoor UEs:ITU InH For outdoor UEs:ITU InH NLOS
Antenna configuration	2Tx2Rx in DL, Cross-polarized	
Number of clusters/buildings per macro cell geographical area	1	
Number of small cells per cluster	2	
Number of small cells per Macro cell	2	
Number of UEs	60 UEs per macro cell geographical area are recommended when FTP model 3 is used	
UE dropping	2/3 of UEs are dropped within the hotzone buildings 1/3 of UEs are dropped throughout the macro geographical area (including hotzones) o A UE is an indoor UE if it is located within a hotzone building o Additionally, a UE not located within a hotzone building is classified as an indoor UE with x% probability, where x>=0. Companies should indicate the value x when presenting the results. Revisit if it diverges much from 20%/80% outdoor/indoor UE splitting	
Radius for small cell dropping in a cluster	N/A	
Radius for UE dropping in a cluster	N/A	
Minimum distance (2D distance)	N/A	
	3m	
	Macro –building center: 100m	
	Macro – UE : 35m	
	building center-building center: 130m	
Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.	
UE receiver	MMSE-IRC as baseline	
UE noise figure	9dB	
UE speed	3km/h	
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.	
Network synchronization	Baseline is synchronized; if an evaluated feature requires synchronisation, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.	

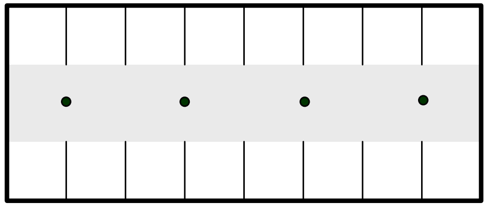
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms,10ms,50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

When dual-strip model is used for small cells, the following parameters apply on top of the above table.

	Macro cell	Small cell
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 Based on dual-stripe urban model TR36.814. Random number of floors uniform between 2 and 5.
Distance-dependent path loss	Macro-to UE link: default is ITU UMa [referring to Table B.1.2.1-1 in TR36.814] 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability Linear height dependent adjustments based on measurements of height dependent gain for non-line of sight links o Linear gain factor – if present, possible range (1.1 – 1.5)dB/m (FFS) o PL = Max(Non-LOS PL +Gain, LOS PL) o Height Dependent LOS probability FFS Note: it may be updated according to the agreements in the 3D MIMO SI.	SC-to-Indoor UE (same building): PL (dB) = 38.46 + 20 log10R + 0.5*$d_{2D,indoor}$ + 18.3 $n^{((n+2)/(n+1)-0.46)}$ + q*L_{iw}+ delta(fc) SC-to-outdoor UE: PL (dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) + 0.5*$d_{2D,indoor}$ + q*L_{iw} + Low(fc) + delta(fc) SC-to-Indoor UE (in a different building): PL(dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) +0.5*$d_{2D,indoor}$ + q*L_{iw} + Low1(fc) + Low2(fc) + delta(fc) Note: if UE is in virtual building, the $d_{2D,indoor}$ is uniform with [0,25]m where, delta(3.5GHz) = 20*log10(3.5/2) = 4.8 dB,

Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	Outerwall penetration loss: Low(3.5GHz)=Low1(3.5GHz)=Low2(3.5GHz)=23dB. Innerwall penetration loss: L_{iw} =5 dB.
Number of small cells per cluster	[Number of 10m x 10m units in a cluster] x[Probability of SC per unit of 10m x 10m] 5% probability of having SC per unit of 10m x 10m SCs are randomly dropped in the clusters.	
UE dropping	2/3 of UEs are dropped within the hotzone buildings o Hotzone UEs are dropped uniformly among total number of floors in the macro dropping area 1/3 of UEs are dropped throughout the macro geographical area (including hotzones) o A UE is an indoor UE if it is located within a hotzone building o Additionally, a UE not located within a hotzone building is classified as an indoor UE with x% probability, where x>=0. Companies should indicate the value x when presenting the results. Revisit if it diverges much from 20%/80% outdoor/indoor UE splitting	
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells. The results can be reported in the following forms -Distributions of per small cell throughputs -Distribution of macro area throughputs -Distribution of system wide throughputs	

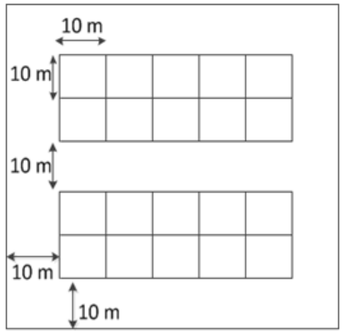
A.1.4 Scenario 2b (dense)

	Macro cell	Small cell
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 The outdoor clusters in Scenario #2a is replaced by the ITU Indoor Hotspots, the hotspots are uniformly random within macro geographical area. The detailed parameters setting for an indoor hotspot can refer to A.2.1.1.5 in TR36.814; 4 small cells per floor, 1 or 2 floors; ISD between small cells within the same floor is 30m.
System bandwidth per carrier	10MHz	10MHz
Carrier frequency	2.0GHz	3.5GHz
Carrier number	1	1 or 2
Total BS TX power (Ptotal per carrier)	46dBm	24dBm
Distance-dependent path loss	ITU UMa[referring to Table B.1.2.1-1 in TR36.814] h_{UT} = 1.5 m for the outdoor UEs and indoor UEs in the first floor. h_{UT} = 7.5 m for the indoor UEs in the second floor. 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability	For indoor UEs in the same building: ITU InH [referring to Table B.1.2.1-1 in TR36.814] For outdoor UEs and indoor UEs in another building, working assumption is ITU UMi [referring to Table B.1.2.1-1 in TR36.814]. h_{BS} = 6m and 12m for the eNBs in the first floor and second floor respectively. h_{UT} = 1.5m for outdoor UEs and the first floor UEs in another building. h_{UT} = 7.5m for the second floor UEs in another building. 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability
Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	For indoor UEs in the same building: 0dB within the same floor;18.3 dB between different floors For outdoor UEs: 23dB+0.5din (d_{in} : independent uniform random value between[0, min(25,UE-to-eNB distance)] for each link) For indoor UEs in another building: 46 dB+0.5(d_{in_1}+ d_{in_2}) (d_{in_1} and d_{in_2} are independent uniform random value between[0, min(25,UE-to-eNB distance)] for each link)

Shadowing	ITU UMa according to Table A.1-1 of 36.819 Working assumption is that 3D distance is used for shadowing correlation distance	ITU InH [referring to Table A.2.1.1.5-1 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	3D, referring to TR36.819	2D Omni-directional is baseline; directional antenna is not precluded
Antenna Height:	25m	6m
UE antenna Height	1.5m	
Antenna gain + connector loss	17 dBi	5dBi
Antenna gain of UE	0 dBi	
Fast fading channel between eNB and UE	ITU UMa according to Table A.1-1 of 36.819	For indoor UEs: ITU InH For outdoor UEs: ITU InH NLOS
Antenna configuration	2Tx2Rx in DL, Cross-polarized	
Number of clusters/buildings per macro cell geographical area	1, 2, optional of 4	
Number of small cells per cluster	4, 8	
Number of small cells per Macro cell	[4,8]*Number of buildings per macro cell geographical area	
Number of UEs	60 UEs per macro cell geographical area are recommended when FTP model 3 is used	
UE dropping	2/3 of UEs are dropped within the hotzone buildings 1/3 of UEs are dropped throughout the macro geographical area (including hotzones) o A UE is an indoor UE if it is located within a hotzone building o Additionally, a UE not located within a hotzone building is classified as an indoor UE with x% probability, where x>=0. Companies should indicate the value x when presenting the results. Revisit if it diverges much from 20%/80% outdoor/indoor UE splitting	
Radius for small cell dropping in a cluster	N/A	
Radius for UE dropping in a cluster	N/A	
Minimum distance (2D distance)	N/A	
	3m	
	Macro –building center: 100m	
	Macro – UE : 35m	
	building center-building center: 130m	
Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.	
UE receiver	MMSE-IRC as baseline	
UE noise figure	9dB	

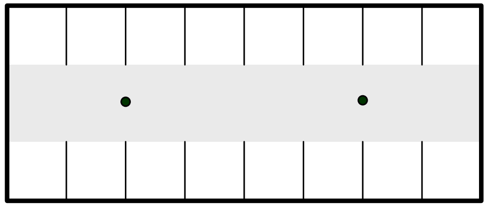
UE speed	3km/h
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.
Network synchronization	Baseline is synchronised; if an evaluated feature requires synchronisation, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms,10ms,50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

When dual-strip model is used for small cells, the following parameters apply on top of the above table.

	Macro cell	**Small cell**
Layout	Hexagonal grid, 3 sectors per site, case 1 Both 19 Macro sites and 7 Macro sites can be used. Companies should indicate whether 19 or 7 sites are used when presenting the results.	 Based on dual-stripe urban model TR36.814. Random number of floors uniform between 2 and 5.
Distance-dependent path loss	Macro-to UE link: default is ITU UMa [referring to Table B.1.2.1-1 in TR36.814] 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability Linear height dependent adjustments based on measurements of height dependent gain for non-line of sight links o Linear gain factor – if present, possible range (1.1 – 1.5)dB/m (FFS) o PL = Max(Non-LOS PL +Gain, LOS PL) o Height Dependent LOS probability FFS Note: it may be updated according to the agreements in the 3D MIMO SI.	SC-to-Indoor UE (same building): PL (dB) = $38.46 + 20 \log10R + 0.5 {*} d_{2D,indoor} + 18.3\, n^{((n+2)/(n+1)-0.46)} + q {*} L_{iw} +$ delta(fc) SC-to-outdoor UE: PL (dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) + $0.5 {*} d_{2D,indoor} + q {*} L_{iw}$ + Low(fc) + delta(fc) SC-to-Indoor UE (in a different building): PL(dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) +$0.5 {*} d_{2D,indoor} + q {*} L_{iw}$ + Low1(fc) + Low2(fc) + delta(fc) Note: if UE is in virtual building, the $d_{2D,indoor}$ is uniform with [0,25]m where, delta(3.5GHz) = 20*log10(3.5/2) = 4.8 dB,

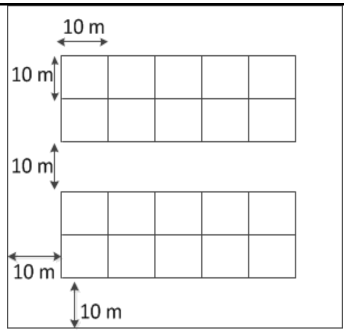
Penetration	For outdoor UEs:0dB For indoor UEs: 20dB+0.5d_{in} (d_{in} : independent uniform random value between [0, min(25,d)] for each link)	Outerwall penetration loss: Low(3.5GHz)=Low1(3.5GHz)=Low2(3.5GHz)=23dB. Innerwall penetration loss: L_{iw} =5 dB.
Number of small cells per cluster	[Number of 10m x 10m units in a cluster] x[Probability of SC per unit of 10m x 10m] 20% probability of having SC per unit of 10m x 10m SCs are randomly dropped in the clusters.	
UE dropping	2/3 of UEs are dropped within the hotzone buildings o Hotzone UEs are dropped uniformly among total number of floors in the macro dropping area 1/3 of UEs are dropped throughout the macro geographical area (including hotzones) o A UE is an indoor UE if it is located within a hotzone building o Additionally, a UE not located within a hotzone building is classified as an indoor UE with x% probability, where x>=0. Companies should indicate the value x when presenting the results. Revisit if it diverges much from 20%/80% outdoor/indoor UE splitting	
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells. The results can be reported in the following forms -Distributions of per small cell throughputs -Distribution of macro area throughputs -Distribution of system wide throughputs	

A.1.5 Scenario 3 (sparse)

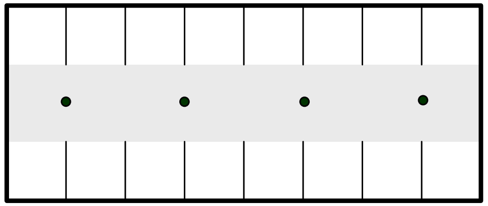
	Small cell, Macro cell is not modelled
Layout	 Referring to A.2.1.1.5 in TR 36.814
System bandwidth per carrier	10MHz
Carrier frequency	3.5GHz
Carrier number	1
Total BS TX power (Ptotal per carrier)	24dBm
Distance-dependent path loss	ITU InH [referring to Table B.1.2.1-1 in TR36.814] 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability
Penetration	0dB
Shadowing	ITU InH [referring to Table A.2.1.1.5-1 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	2D Omni-directional is baseline; directional antenna is not precluded
Antenna Height:	6m
UE antenna Height	1.5m
Antenna gain + connector loss	5dBi
Antenna gain of UE	0 dBi
Fast fading channel between eNB and UE	ITU InH
Antenna configuration	2Tx2Rx in DL, Cross-polarized
Number of clusters/buildings per macro cell geographical area	N/A
Number of small cells per cluster	N/A
Number of small cells per Macro cell	N/A
Number of UEs	10 UEs per small cell
UE dropping	Randomly and uniformly distributed over area per floor
Radius for small cell dropping in a cluster	N/A
Radius for UE dropping in a cluster	N/A
Minimum distance (2D distance)	Small cell-UE: 3m

Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.
UE receiver	MMSE-IRC as baseline
UE noise figure	9dB
UE speed	3km/h
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.
Network synchronization	Baseline is synchronized; if an evaluated feature requires synchronisation, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms,10ms,50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

When dual-strip model is used for small cells, the following parameters apply on top of the above table.

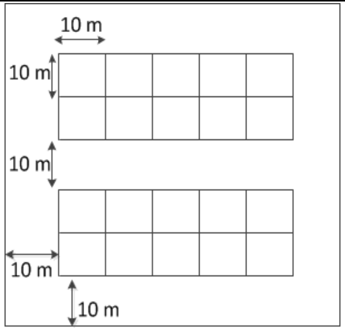
Layout	 Based on dual-stripe urban model TR36.814. Random number of floors uniform between 2 and 5.
Distance-dependent path loss	SC-to-Indoor UE (same building): PL (dB) = 38.46 + 20 log10R + 0.5*$d_{2D,indoor}$ + 18.3 $n^{((n+2)/(n+1)-0.46)}$+ q*L_{iw}+ delta(fc) SC-to-outdoor UE: PL (dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) + 0.5*$d_{2D,indoor}$ + q*L_{iw} + Low(fc) + delta(fc) SC-to-Indoor UE (in a different building): PL(dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) +0.5*$d_{2D,indoor}$ + q*L_{iw} + Low1(fc) + Low2(fc) + delta(fc) Note: if UE is in virtual building, the $d_{2D,indoor}$ is uniform with [0,25]m where, delta(3.5GHz) = 20*log10(3.5/2) = 4.8 dB,
Penetration	Outerwall penetration loss: Low(3.5GHz)=Low1(3.5GHz)=Low2(3.5GHz)=23dB. Innerwall penetration loss: L_{iw} =5 dB.
Number of small cells per cluster	[Number of 10m x 10m units in a cluster] x[Probability of SC per unit of 10m x 10m] 5% probability of having SC per unit of 10m x 10m SCs are randomly dropped in the clusters.

A.1.6 Scenario 3 (dense)

	Small cell, Macro cell is not modelled
Layout	 The detailed parameters setting can refer to A.2.1.1.5 in TR36.814; 4 small cells per floor, 2 floors, ISD between small cells within the same floor is 30m.
System bandwidth per carrier	10MHz
Carrier frequency	3.5GHz
Carrier number	1 or 2
Total BS TX power (Ptotal per carrier)	24dBm
Distance-dependent path loss	ITU InH [referring to Table B.1.2.1-1 in TR36.814] 3D distance between an eNB and a UE is applied Working assumption is that 3D distance is also used for: break point distance LOS probability
Penetration	0dB within the same floor;18.3dB between different floors
Shadowing	ITU InH [referring to Table A.2.1.1.5-1 in TR36.814] Working assumption is that 3D distance is used for shadowing correlation distance
Antenna pattern	2D Omni-directional is baseline; directional antenna is not precluded
Antenna Height:	6m
UE antenna Height	1.5m
Antenna gain + connector loss	5dBi
Antenna gain of UE	0 dBi
Fast fading channel between eNB and UE	ITU InH
Antenna configuration	2Tx2Rx in DL, Cross-polarized
Number of clusters/buildings per macro cell geographical area	N/A
Number of small cells per cluster	N/A
Number of small cells per Macro cell	N/A
Number of UEs	5/10 UEs per small cell
UE dropping	Randomly and uniformly distributed over area per floor
Radius for small cell dropping in a cluster	N/A
Radius for UE dropping in a cluster	N/A
Minimum distance (2D distance)	Small cell-UE: 3m

Traffic model	Baseline: FTP Model 1 as in TR 36.814 Alternative (should be used when evaluating techniques where uneven load with larger time scale needs to be addressed): FTP Model 3: based on FTP model 2 with the exception that packets for the same UE arrive according to a Poisson process and the transmission time of a packet is counted from the time instance it arrives in the queue 0.5Mbytes file size. The offered traffic is generated per macro cell geographical area when FTP model 1 is used.
UE receiver	MMSE-IRC as baseline
UE noise figure	9dB
UE speed	3km/h
Cell selection criteria	Baseline: RSRP for intra-frequency and RSRQ for inter-frequency, with cell common bias if CRE is applied.
Network synchronization	Baseline is synchronized; if an evaluated feature requires synchronisation, this should be stated; evaluations without synchronization are not precluded, and the assumed synchronization accuracy in such simulations should be stated.
Backhaul assumptions	• The latency and throughput values for non-ideal backhaul indicated in Table 6.1-1 of 36.932 are the baseline assumptions -The latency values of {2ms,10ms,50ms} are recommended for evaluation. • Whether and how the backhaul assumptions are explicitly modelled in the simulations should be indicated by companies when presenting the results. • Proposals considering backhaul assumptions should analyze the influence of these assumptions on the delivery of the information to be exchanged and on the access network performance metrics.
Performance metrics	Mean, 5%/50%/95% UPT at the given offered traffic (for example the offered traffic resulting in a resource utilization of e.g., 10%, 30%, or 50%, for a reference scheme). Note: performances should be evaluated for users in all area and for users served by small cells.

When dual-strip model is used for small cells, the following parameters apply on top of the above table.

Layout	 Based on dual-stripe urban model TR36.814. Random number of floors uniform between 2 and 5.
Distance-dependent path loss	SC-to-Indoor UE (same building): PL (dB) = 38.46 + 20 log10R + 0.5*$d_{2D,indoor}$ + 18.3 n $^{((n+2)/(n+1)-0.46)}$+ q*L_{iw}+ delta(fc) SC-to-outdoor UE: PL (dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) + 0.5*$d_{2D,indoor}$ + q*L_{iw} + Low(fc) + delta(fc) SC-to-Indoor UE (in a different building): PL(dB) = max(15.3 + 37.6log10R, 38.46 + 20log10R) +0.5*$d_{2D,indoor}$ + q*L_{iw} + Low1(fc) + Low2(fc) + delta(fc) Note: if UE is in virtual building, the $d_{2D,indoor}$ is uniform with [0,25]m where, delta(3.5GHz) = 20*log10(3.5/2) = 4.8 dB,
Penetration	Outerwall penetration loss: Low(3.5GHz)=Low1(3.5GHz)=Low2(3.5GHz)=23dB. Innerwall penetration loss: L_{iw} =5 dB.
Number of small cells per cluster	[Number of 10m x 10m units in a cluster] x[Probability of SC per unit of 10m x 10m] 20% probability of having SC per unit of 10m x 10m SCs are randomly dropped in the clusters.

- For all the scenarios, CRS interference modelling is recommended for the evaluations that are sensitive to the CRS interference. Whether and how the CRS interference is modelled should be provided by each company. Additional error modelling of decoding of DL control channel and broadcast channel is not precluded.
- ITU model is baseline for indoor model of Scenario #2b and Scenario #3. Dual stripe model can also be used for Scenario #2b and Scenario #3.
- Working assumption is that I-O distance dependent path loss model for Scenario #2b is UMi. To be revisited in RAN1 #72bis meeting.

A.2 Uplink specific evaluation parameters

Total UE TX power	23dBm
Antenna configuration	1 Tx 2Rx baseline • Optional 2Tx 2 Rx • Cross-polarized
eNB receiver	MMSE-IRC as baseline
eNB noise figure	7 dB
UL Overhead	SRS overhead - 5 ms period • 4 PRBs for PUCCH
UL Power control	Details provided by each company

A.3 Evaluation assumptions for spectrum efficiency enhancements

A.3.1 256QAM

Link level simulation for 256QAM	
EVM	[28 dB(4%)], [25 dB(6%)] for small cell 22 dB(8%) for macro cell
Receiver impairment	Companies to state what is assumed until feedback is received from RAN4

System level simulation for 256QAM	
EVM	[28 dB(4%)], [25 dB(6%)] for small cell 22 dB(8%) for macro cell
Transmission scheme	SU-MIMO with rank adaptation
CRS configuration	Antenna ports 0,1
Receiver impairment	Companies to state what is assumed until feedback is received from RAN4
CRS interference should be explicitly modelled	
Fast fading should be included	

A.3.2 Common link level simulation for spectrum efficiency enhancements

Bandwidth	10MHz
Carrier frequency	3.5G
Channel model and Doppler frequency	EPA - The delay profiles refer to 36.101 Table B.2.1-2 - Maximum Doppler frequency: 10Hz
Transmission mode	TM10
MIMO configuration	2x2 with low correlation - refer to 36.101 B.2.3.2
CRS configuration	Antenna ports 0,1
CSI reference signals	2-port NZP CSI-RS with 5ms period One CSI-IM configured as ZP CSI-RS with 5ms period
DMRS	Port 7&8
Rank adaptation	On
PMI	Based on UE measurement and feedback
Link adaptation	On
HARQ	On
UE receiver	MMSE-IRC
Channel estimation	Practical
Interference estimation	Practical
PDP estimation	Practical
Received timing delay (us)	0
Frequency offset (Hz)	0
UE speed	3km/h, other UE speeds can be evaluated optionally
Overhead assumption	2 PDCCH symbols; PBCH/PSS/SSS; 2-port CRS; 2-port CSI-RS with 5ms period One CSI-IM configured as ZP CSI-RS with 5ms period 1 or 2 DMRS ports;
Metric	Spectrum efficiency [bps/Hz]
NOTE: Explicit modelling of CRS interference of one interfering cell is recommended; if some other modelling is used, it is to be described	

A.4 Evaluation assumptions for efficient operation

A.4.1 Evaluation assumptions for discovery

- The baseline is the discovery performance based on existing signals such as PSS/SSS/CRS.
- The uniformly distributed small cells can be optionally used for the evaluation of discovery RS.

- Metrics for evaluation:
    - UE battery consumption for discovery
    - Number of supportable individually identifiable small cells
        - Baseline is current number of supported PCIDs
        - Identify whether the current number is sufficient
    - Number of detectable cells in the chosen scenarios
        - Target set of detectable cells:
            - Actual target set of detectable cells per carrier frequency should be determined based on gain achievable with, such as, interference coordination and load balancing.
            - Proposals for target set definition:
                - Alt.1: Small cells within RSRP gap = Y, Y=15 dB is baseline at this stage.
                - Alt.2: Top N small cells of a UE with RSRP >= X, N >= 3 and X=-127 dBm are baseline at this stage.
        - Target false alarm probability
            - 0.001 is used for initial evaluation purpose and it should not impact the RAN4 requirement design
            - False alarm probability is defined as a detection probability of cells in the case of noise only input
            - In the legacy mechanism, the conclusive false alarm probability in the PSS/SSS detection should satisfy the above target
        - Detectability as defined in 36.133 for initial evaluation
    - Probability of detecting a cell as a function of distance
    - Detection time (e.g. taking into account ability to support small cell DTX operation / energy consumption)
    - Ability to estimate the signal strength of a small cell
    - Overhead
    - Impact on legacy UEs
    - Detection probabilities and RSRP measurement accuracies for at least top 3 small cells are evaluated
    - Number of measurement samples, i.e., PSS/SSS/CRS subframes, used for the detection/measurement should be shown (at least 1 subframe case should be evaluated)
- Begin by evaluating performance of legacy mechanism (i.e. PSS/SSS/CRS)
- If inadequacies are identified with the legacy mechanism, evaluate:
    - first, approaches based on modified SS/RS
    - second, approaches based on new discovery signal
- Evaluation methodology:
    - Up to companies to decide between e.g.:
        - Alt.1:
            - Step-0:system level simulation to model the interference profile for link level simulation
            - Step-1: link level simulation to derive the performance curve (i.e., SINR – detection probability) based on the interference profile derived by the Step-0 simulation
            - [FFS] Step-2: system level simulation based on LLS to SLS mapping
        - Alt.2: System level evaluation including link-level signal generation and detection
- Scenario:
    - Scenario 2a with dense deployment of small cells
        - Baseline: 1 cluster per cell, 10 cells per cluster; other values can also be evaluated.
- Other baseline assumptions:
    - UEs only within cluster region are considered for the evaluation
    - It is assumed that UE does not have any PCI information of surrounding small cells in the evaluation of legacy mechanism

- Synchronized transmission of PSS/SSS/CRS with timing/frequency offsets is assumed
- Full buffer traffic load is assumed for the discovery performance evaluation
- +/- 3 µs timing offset and +/- 0.1 ppm frequency offset among small cells are used
- EPA multipath fading channel (3 km/h) is used
- Actual detection/measurement algorithms should be implemented

A.4.2 Evaluation assumptions for small cell on/off

Scenario	Scenario 1, Scenario 2a
Schemes (note 1)	1. Semi-static on/off 2. On/off with feasible time scale 3. Dynamic on/off
Time scale	TBD
Scheduler	Proportional fair scheduler One packet is scheduled only from one network node
Traffic load (note 2)	Resource utilization of {20%, 40%, 60%}
Traffic model	Scheme 1: FTP 3 with 30 UEs Scheme 2: FTP 1 Scheme 3: FTP 1 or FTP 3 with 30 UEs
Cluster configuration	1 cluster of 10 small cells per cluster 1 cluster of 4 small cells per cluster
CRS interference	CRS interference on PDSCH is modelled in all scenario and follows Alt2 in R1-112856
ABS with CRS-IC	ABS together with and without CRS-IC should be considered in scenario 1 and follow R1-112856
CRS overhead	2 CRS ports Macro cell, cell_Ids: Planned Small cell, cell_Ids: Details provided by each company
Number of MBSFN subframes configured	0 and 6
Transmission mode	SU-MIMO 2Tx/2Rx cross-pol TM10
Control channel overhead	NA
Backhaul	Non-ideal backhaul
Cell association (note 3)	For scenario 1 RSRP + bias of at least 6 dB and 9 dB should be simulated For scenario 2a RSRQ + bias with realistic buffer Bias of 0 dB as baseline
NOTE 1: Baseline for on/off study is no small cell on/off NOTE 2: Across all cells in the most loaded layer in the reference scheme NOTE 3: Not to limit cell association study	

Annex B: Change history

Change history					
Date	**TSG #**	**TSG Doc.**	**Subject/Comment**	**Old**	**New**
2013-01	RAN1#72	R1-130019	Draft skeleton TR		0.0.1
2013-04	RAN1#72b	R1-131685	Inclusion of small cell scenarios and evaluation assumptions	0.0.1	0.1.0
2013-05	RAN1#73	R1-132812	Inclusion of agreements made in RAN1 #72bis on additional evaluation assumptions, DL/UL DMRS overhead reduction, small cell discovery and interference avoidance and coordination.	0.1.0	0.3.0
2013-08	RAN1#74	R1-134003	Inclusion of agreements made in RAN1 #73 on control signalling enhancements, higher order modulation, radio-based synchronization mechanisms, evaluation assumptions on small cell discovery and small cell on/off	0.3.0	0.4.0
2013-08	RAN1#74	R1-134023 (RP-131187)	Inclusion of agreements made in RAN1 #74 on small cell on/off, small cell discovery, enhanced power control/adaptation, enhancement of frequency domain pow er control and/or ABS to multi-cell scenarios, load balancing/shifting (including cell association), radio-interface based synchronization mechanisms and physical layer support of dual connectivity	0.4.0	1.0.0
2013-09	RAN#61	RP-131321	MCC clean-up	1.0.0	1.0.1