Qualcomm Technologies, Inc.

LTE Small Cell SON Test Cases

Functionality and Interworking

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Questions or comments: https://support.cdmatech.com/

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Revision history

Revision	Date	Description
A	June 2015	Initial release

Contents

Figures

Tables

1 Introduction

Self-Organizing Network (SON) functions are widely recognized as a key enabler of small cells. 3GPP defines SON framework and specifies signaling support for some SON functions for LTE networks. Algorithms are generally left to implementation, and test cases for verification are not defined. There has been previous work in some industry forums, such as Small Cell Forum (SCF) and NGMN on defining requirements and best practices for SON functions, including inter-vendor interworking aspects of LTE small cells [S1, S2, S3].

In this document, test cases are provided to verify proper implementation and interworking of some key SON functions for LTE small cells. These test cases can provide a starting point for operators and industry forums such as SCF to form a widely agreed test framework which ensures robust SON performance and inter-vendor working.

The document covers PCI Selection, ANR, ICIC, MRO, and FHM functions.

1.1 Conventions

Blue text indicates a hyperlink to another location.

1.2 References

Table 1-1 lists reference documents that may include standards and general resource documents.

Table 1-1 Reference documents and standards

Ref.	Document	
Standards		
S1	BBF TR-196 – Femto Access Point Service Data Model [http://www.broadband-forum.org/cwmp/tr-196-2-0-1.html]	
S2	Small Cell Forum Document 083.05.01, *SON API for Small Cells,* March 2015	
S3	NGMN Alliance – *Recommended Practices for Multi-vendor SON Deployment, Deliverable D2*, January 2014	
S4	Telecommunication management; Performance Management (PM); Performance Measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN)	3GPP TS 32.425
S5	3GPP (Release 9); *LTE; General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Networks (E-UTRAN) access*;	ETSI TS 23.401 v9.16.0
S6	3GPP (Release 9); *LTE;* Telecommunication Management; Performance Management (PM); Performance Measurements Home Enhanced Node B (HeNB) Subsystem (HeNS)	ETSI TS 32.453 v10.0.0

Ref.	Document	
S7	3GPP (Release 9); *LTE; Telecommunication Management; Self-Organizing Networks (SON) Policy Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)*	ETSI TS 32.522 v9.3.0
S8	3GPP (Release 9); *LTE; 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)*	ETSI TS 32.592 v9.3.0
S9	3GPP (Release 9); *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2*	ETSI TS 36 300 v9.10.0
S10	3GPP (Release 9); *LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)*	ETSI TS 36.423 v9.6.0

1.3 Acronyms

Table 1-2 lists acronyms and definitions that are used in this document.

Table 1-2 Acronyms

Acronym	Definition
3GPP	3rd Generation Partnership Project, the organization specifying standards for Long-Term Evolution (LTE) and other systems
ANR	Automatic Neighbor Relation
API	Application Programming Interface
BLER	Block Error Rate
BW	Bandwidth
CC	Cell Center
CCU	Cell-Center UE
CE	Cell Edge
CER	Cell-Edge Resources
CEU	Cell-Edge UE
CIO	Cell Individual Offset
CQI	Channel-Quality Indication
CSI	Channel State Information
cSON	Centralized SON
DL	Downlink
DRX	Discontinuous Reception
DTCH	Dedicated Traffic Channel
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
ECGI	E_UTRAN Cell Global Identifier
eNB	Evolved NodeB
EPRE	Energy Per Resource Element
E-RAB	E-UTRAN Radio Bearer
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FHM	Frequent Handover Mitigation Algorithm

Acronym	Definition
FHO	Forward Handover
FSM™	Femtocell Station Modem
GBR	Guaranteed Bit Rate
GPRS	General Packet Radio Service
HeMS	HeNB Management System
HeNB	Home eNodeB (aka LTE femtocell)
HeNS	HeNB Subsystem
HO	Handover
ICIC	Inter-cell Interference Coordination
IE	Information Element
IIR	Infinite Impulse Response
IM	Information Management
IRP	Integration Reference Point
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MAC	Media Access Control
MIB	Master Information Block
MLB	Mobility Load Balancing
MRO	Mobility Robustness Optimization
NL	Network Listen
NLM	Network Listen Measurements
NR	Neighbor Relations
NRM	Network Resource Model
NRT	Neighbor Relation Table
OAM	Operations, Administration, and Maintenance
OEM	Original Equipment Manufacturer
PCI	Physical Cell Identity
PDSCH	Physical Downlink Shared Channel
PHY	Physical Layer
PL	Path Loss
PRB	Physical Resource Block
QoS	Quality of Service
RAT	Radio Access Technology
RF	Radio Frequency
RLF	Radio Link Failure
RM	Resource Management
RNTI	Radio Network Temporary Identifier
RNTP	Relative Narrowband Transmit Power
RRC	Radio Resource Control
RRM	Radio Resource Management
RSCP	Received Signal Code Power
RSRP	Reference Signal Received Power

Acronym	Definition
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
SC	Small Cell
SFFR	Soft-Fractional Frequency Reuse
SIB	System Information Block
SINR	Signal-to-Interface Plus Noise Ratio
SON	Self-Organizing Network
TNL	Transport Network Layer
TPM	Transmit Power Management
TTT	Time to Trigger
TX	Transmitter
UE	User Equipment
UL	Uplink
UTRAN	Universal Terrestrial Radio Access Network
VA	Variable Attenuator
X2AP	X2 Application Protocol

1.4 Generic test setup

Figure 1-1 shows an example of a generic cabled test setup that can be used for the test cases in the subsequent chapters. A UE is connected to three small cells (SC1-SC3) through a splitter combiner and variable attenuators (VA1-VA3). Information from the UE can be extracted from the logging tool. Information from the small cells can be extracted through their respective logging mechanisms (not shown in the figure). Other elements of end-to-end network (or simulators thereof) are not shown in the figure, but are assumed to be present to support test execution.

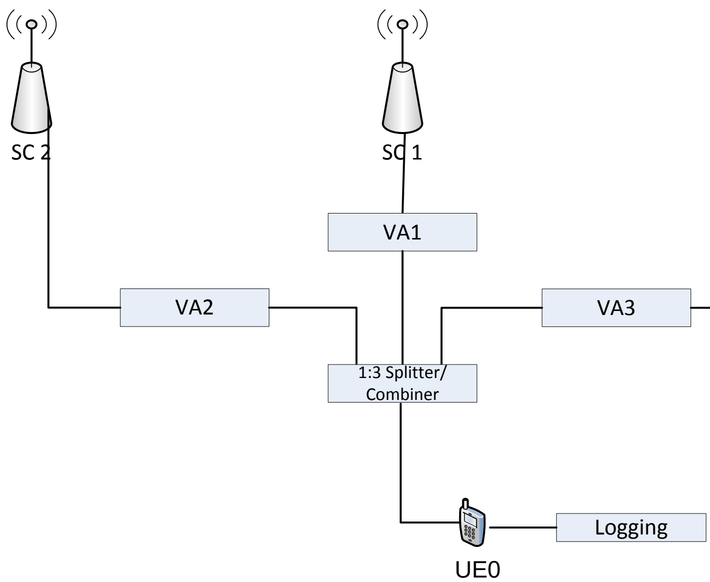


Figure 1-1 Generic test setup (some modifications may be needed for different test cases)

2 Automated Configuration of Physical Cell Identity

2.1 SON.PCI_1

Title: PCI selection at bootup

Revision: 0.01

Description: PCI selection at bootup with NLM enabled

Test setup and procedure

Select one PCI from the list provisioned by OAM. The selected PCI shall not be detected by NLM.

1. Clear persisted data, provision SC 1, and set SC 1 to initial state.Provision the available PCI list as {100, 101} for SC 1.
2. Configured a neighbor SC (SC 2) with PCI 100. Connect the two cells with a fixed attenuator of 70dB. Set SC 2's reference signal transmit power at -15dBm.
3. Power on SC 1 with NL enabled, and wait for NL measurement and PCI selection.
4. Power cycle the UE and camp on SC 1; read the UE log to verify the serving cell's PCI.
5. Repeat the procedure 20 times and record the selected PCI for each run.

Expected outcome

1. Verify from UE log that SC selects PCI 101 all the time.

Notes

- This test assumes that NL is available in the platform. If NL is not available, this test case is not applicable.
- The neighbor SC (SC 2) should be up and running before SC NL module start scanning.
- The neighbor SC (SC 2) should be up and running before SC NL module start scanning.

2.2 SON.PCI_2

Title: Persisted PCI not selected (detected neighbor)

Revision: 0.01

Description: Persisted PCI is not selected at reboot, due to an NL detected neighbor

Test setup and procedure

OAM configures an available PCI list to SON. Upon reboot, SON detects a conflict with the previous PCI and uses another PCI.

1. Provision the available PCI list as {100, 101} for SC 1.
2. Persistency data is available, with 101 being the persisted PCI.
3. Configured a neighbor SC (SC 2) with PCI 101. Connect the two cells with a fixed attenuator of 70dB. Set SC 2's reference signal transmit power at -15dBm.
4. Power on SC with NL enabled, and wait for NL measurement, persistency determination, and PCI selection.
5. Observe that persistency determination decides no change of location.
6. Observe that NL detects PCI 101 is used by a neighbor.
7. Observe that PCI selection chooses PCI 100.
8. Power cycle the UE and camp on SC; read the UE log to verify the serving cell's PCI.
9. Repeat the procedure 20 times and record the selected PCI for each run.

Expected outcome

1. Verify from UE log that SC selects PCI 100 all the time.

Notes

- This test assumes that NL is available in the platform. If NL is not available, this test case is not applicable.
- The neighbor SC (SC 2) should be up and running before SC NL module starts scanning.

2.3 SON.PCI_3

Title: Persisted PCI not selected (not provisioned)

Revision: 0.01

Description: Persisted PCI is not selected when it is not part of the new provisioned PCI list.

Test setup and procedure

OAM configures an available PCI list to SON. Upon reboot, SON detects no conflict with the previous PCI, but a new available PCI list and re-uses it for persistency. Provision the available PCI list as {100, 101} for SC 1.

1. Provision the available PCI list as {200.. 203}.
2. Persistency data is available, with 101 being the persisted PCI.
3. Observe that persistency determination decides no change and hence persisted
4. Observe that PCI selection chooses a PCI between 200 and 203.
5. Power cycle the UE and camp on SC; read the UE log to verify the serving cell's PCI.

Expected outcome

1. Any PCI between 200 and 203 can be selected.

Notes

- This test assumes that NL is available in the platform. If NL is not available, NL related aspects do not apply and tests should be performed without NL dependency (e.g., using other inputs such as OAM, UE) whenever applicable.

2.4 SON.PCI_4

Title: Persisted PCI selection

Revision: 0.01

Description: PCI selection based on persisted PCI, OAM-provisioned neighbors' PCIs, and NL detected PCIs

Test setup and procedure

Both the persisted PCI and an initial NRT from OAM-added neighbors will be used for PCI selection to avoid PCI conflict.

1. Configure PhyCellId as 201 and persist the PCI for the serving SC (SC 1).
2. OAM adds three intra-frequency neighbors with PCI 200, 201, 203 for SC 1.
3. Provision the available PCI list as {200,201,202,203,204} for SC 1.
4. Configured a neighbor SC (SC 2) with PCI 204. Connect the two cells with a fixed attenuator of 70dB. Set SC 2's reference signal transmit power at -15dBm.
5. Reboot SC 1 with NL enabled, and wait for NL measurement, persistency determination, and PCI selection.
6. Observe that PCI selection chooses PCI 202.
7. Power cycle the UE and camp on SC; read the UE log to verify the serving cell's PCI.
8. Repeat the procedure 20 times and record the selected PCI for each run.

Expected outcome

1. PCI 202 should be selected all the time.

Notes

- This test assumes that NL is available in the platform. If NL is not available, NL related aspects do not apply and tests should be performed without NL dependency (e.g., using other inputs such as OAM, UE) whenever applicable.

2.5 SON.PCI_5

Title: PCI selection procedure

Revision: 0.01

Description: Test to verify the general PCI selection procedure that combines change of provisioned PCI list, persisted PCI, NL detected PCI, and persistency NRT.

Test setup and procedure

PCI selected during cell start should utilize all of the following information: provisioned PCI list, persisted PCI, NL detected co-channel neighbors, persisted co-channel neighbors.

1. Boot up SC with a single PCI 99 as the provisioned PCI. Observe that PCI 99 is selected and persisted.
2. OAM adds a co-channel neighbor with PCI 101 to NRT. Confirm that this neighbor is added in NRT and persisted.
3. Provision the available PCI list as {100...102}.
4. Connect another SC which is co-channel with the test SC and has PCI 102 to the test SC; adjust the variable attenuator such that the RSRP received at the test SC is -95dBm.
5. Reboot the test SC.
6. Observe that NL detects cochannel neighboring SC PCI=102.
7. Observe the selected PCI of the test SC.

Expected outcome

1. PCI selection algorithm should reject the persisted PCI as it is not in the candidate PCI list provided in PCI_SELECTION_REQ.
2. NL detected PCI 102 should be removed from candidate PCI pool.
3. Persisted NRT neighbor PCI 101 should be removed from candidate PCI pool.
4. PCI 100 should be selected.

Notes

- This test assumes that NL is available in the platform. If NL is not available, NL related aspects do not apply and tests should be performed without NL dependency (e.g., using other inputs such as OAM, UE) whenever applicable.

2.6 SON.PCI_6

Title: GPS based persistency (reuse)

Revision: 0.01

Description: Verification of GPS-based persistency to re-use the previous configuration.

Test setup and procedure

Persistency module restores the previous configuration if the distance between current GPS coordinates and the last stored GPS coordinates does not exceed a configurable threshold.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state (or manually delete persistency data).
2. Power up the SC and observe selected PCI.

Reboot the SC at the same location for 10 times. Observe the persistency determination result and PCI, RSI, NRT selection result.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, persistency determination will decides to re-use persisted data, and the same PCI, RSI & also persistence NRT will be selected.

Notes

- In residential deployment, user may move small cell so location may change. Therefore, priority of test is high for residential SCs.

2.7 SON.PCI_7

Title: GPS based persistency (new)

Revision: 0.01

Description: Verification of GPS-based persistency to start a new configuration

Test setup and procedure

Invoke a new configuration if the distance between the current GPS coordinates and the last stored GPS coordinates exceeds a configurable threshold.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state (or manually delete persistency data).
2. Power up the SC and observe selected PCI.
3. Move the GPS antenna location beyond 50 meters and reboot the SC. Observe the persistency determination result and PCI selection result.
4. Repeat the above procedure 20 times.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, persistency determination will decide to initiate a new configuration, and PCI will again be randomly selected between 100 and 105 and also new RSI will be selected. The persistence NRT will no longer be useful for SC.

Notes

- In residential deployment, user may move small cell so location may change. Therefore, priority of test is high for residential SCs.

2.8 SON.PCI_8

Title: GPS based persistency (persistency disabled)

Revision: 0.01

Description: GPS-based persistency does not take effect when persistency is disabled.

Test setup and procedure

With persistency disabled, Persistency module always initiates a new configuration even if the location does not change.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state (or manually delete persistency data).
2. Power up the SC and observe selected PCI.
3. Reboot the SC at the same location for 10 times. Observe the persistency determination result and PCI selection result.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, confirm that persistency determination is disabled, and PCI will again be randomly selected between 100 and 105.

Notes

- In residential deployment, user may move small cell so location may change. Therefore, priority of test is high for residential SCs.

2.9 SON.PCI_9

Title: Timer based persistency (reuse the previous config)

Revision: 0.01

Description: Verification of timer-based persistency determination to re-use the previous configuration.

Test setup and procedure

Persistency module re-uses the previous configuration if difference between current time stamp and time stamp when the cell was turned off is within the configurable threshold.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state.
2. Observe the selected PCI and Power down the SC.
3. Reboot the SC within 5 minutes at the same location. Observe the persistency determination result and PCI selection result.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, persistency determination will decides to re-use persisted data, and the same PCI will be selected and RSI & also persistence NRT will be selected.

2.10 SON.PCI_10

Title: Timer based persistency (new config)

Revision: 0.01

Description: Verification of timer-based persistency determination to initiate a new configuration.

Test setup and procedure

Persistency module re-uses the previous configuration if difference between current time stamp and time stamp when the cell was turned off is within the configurable threshold.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state.
2. Observe the selected PCI and Power down the SC
3. Reboot the SC in 10 minutes at the same location. Observe the persistency determination result and PCI selection result.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, persistency determination will decides to initiate a new configuration, and hence the PCI selection will again randomly select a PCI between 100 and 105 and also new RSI will select. Persistence NRT will no longer be useful for SC.

2.11 SON.PCI_11

Title: PCI allocation during GPS location change

Revision: 0.01

Description: SON decides to initiate a new configuration based on the GPS location change, even when the timer-based persistency determination result indicates re-use.

Test setup and procedure

Persistency module initiates a new configuration based on GPS location change while timer-based determination indicates otherwise.

1. Power cycle the SC to clear any previously stored persistency data, and set the SC to initial state.
2. Power up the SC and observe selected PCI.
3. Move the GPS antenna location beyond 50 meters and reboot the SC within 5 minutes of the previous bootup. Observe the persistency determination result and PCI selection result.

Expected outcome

1. For the first bootup, a PCI will be selected randomly between 100 and 105. For the subsequent bootup, persistency determination will decides to initiate a new configuration, and hence the PCI selection will again randomly select a PCI between 100 and 105.

Notes

- In residential deployment, user may move small cell so location may change. Therefore, priority of test is high for residential SCs.

2.12 SON.PCI_12

Title: UE assisted PCI confusion detection

Revision: 0.01

Description: PCI confusion detection based on UE reporting

Test setup and procedure

Utilize UE HO statistics and eCGI reading to detect PCI confusion.

1. Power up SC 1 with frequency F1 and PCI 100.
2. Configure SC 2 and SC 3 to be on the same frequency as SC 1 (F1). Configure both SC 2 and SC 3 to have the same PCI 101.
3. Power cycle a UE and make it camp on SC 1. Connect the UE to all three SCs (SC 1/2/3) via three variable attenuators (VA 1/2/3).
4. UE initiates a call on SC 1.
5. Adjust VA 2 such that SC 2 can be detected by the UE with RSRP of -95dBm.
6. Observe NRT update at SC 1 where SC 2 is added to NRT, with PCI 101 and its eCGI.
7. Attached a second UE to both SC 1 and SC 3. Adjust VA 1 and make a call on SC 1. Adjust VA 3 such that SC 3's RSRP at this UE is -95dBm.
8. Adjust VA1 and VA 3 to mimic the first UE moving away from SC 1 and closer to SC 3. Observe that HO fails because SC 1 is trying to handover the UE to SC 2 due to PCI confusion.
9. Re-attach the first UE to SC 1, and repeat Step 7 for 10 times.
10. Observe that PCI confusion is declared after some time.

Expected outcome

1. Based on UE HO reports and eCGI reading, PCI confusion is detected.

2.13 SON.PCI_13

Title: X2 based PCI confusion detection

Revision: 0.01

Description: PCI confusion detection & resolution based on X2 interface

Test setup and procedure

Utilize UE HO statistics and eCGI reading to detect PCI confusion.

1. Configure SC2 as follows: set the PCI value = 203 on F1.
2. Reboot SC2
3. Configure SC1 as follows: set PCI values = 200, 203. Ensure PCI 200 is persisted.
4. Reboot SC1. Verify that SC1 and SC2 are neighbors.
5. Configure SC3 as follows: set PCI values = 200, 203. Other configuration same as SC2.

6. Reboot SC3 Verify that SC2 and SC3 are neighbors.
7. Verify SC2 detects PCI confusion. (Verify confusion detection on SC2 through eNB logs)
8. Observe PCI reselection for one of SC1 or SC3. Verify the timer values for PCI re-selection on SC1 and SC3.

Expected outcome

1. PCI reselection triggered for one of SC1 or SC3.

2.14 SON.PCI_14

Title: PCI confusion

Revision: 0.01

Description: Operation with PCI confusion

Test setup and procedure

Cell exposed to PCI confusion instruct UE for extract cell identification.

1. Configure SC2 as follows: set the PCI value = 242.
2. Reboot SC2.
3. PCI range given to SC1 and SC3 is 200 (so that they do not pick a different PCI).
4. X2 connections exist between the small cells.
5. Reboot SC1 and SC3. Verify that SC1 and SC3 are neighbors of SC2.
6. Attach UE to SC2 and walk towards SC1.
7. Observe successful handover SC2 to SC1.

Expected outcome

1. UE sends MRM with PCI 200.
2. SC2 configures UE for DRX
3. SC2 requests UE to send eCGI for PCI200
4. UE sends eCGI for SC1
5. UE receives HO command to SC1
6. Successful HO to SC1 x

2.15 SON.PCI_15

Title: Intra-frequency handover to PCI with confusion for Rel. 9 UEs that support autonomous gaps

Revision: 0.01

Description: If the serving cell suspects that the small cell PCI belongs to the confusion set, it requests an ECGI reading based on autonomous gaps

Test setup and procedure

1. Configure SC2 as follows: set the PCI value = 242.
2. Reboot SC2.
3. Configure SC1 and SC3 as follows: set PCI values = 200.
4. Reboot SC1, SCI will be added as neighbor of eNB2.
5. Reboot SC3, SC3 will not be added as neighbors of eNB.
6. Attach UE to eNB and walk towards SC3.
7. UE will actually HO to wrong cell SC1.
8. Reattempt HO and walk from eNB2 towards SC3 again.
9. HO should succeed this time.

Expected outcome

1. Macro could either do eCGI query for every HO to SC based on the SC PCI range. Or else after the HO to wrong cell, macro learn about PCI confusion and does eCGI query for second HO.

2.16 SON.PCI_16

Title: PCI selection considering neighbor’s neighbor PCI

Revision: 0.01

Description: PCI selection considering neighbor’s neighbor PCI

Test setup and procedure

SC avoid selecting PCI of the neighbour.

1. Configure SC1 in the following manner: enter the list of PCIs to be considered, enter the list of RSI to be considered (note that RSI list must be at least as long as PCI list).
2. Configure SC2:
   a. Enter a PCI from the list provided to SC1 above; configure the maximum permitted referenceSignalPower; enter the corresponding RSI;
   b. Create a neighbor with PCI (other than PCI of SC1and other than SC2) from the list of PCI’s to be considered
   c. Add neighbor information for parameters enbId, plmnID, myAddr and tac.
3. Reboot SC2.
4. Ensure SC1 is in NL range of SC2.
5. Reboot SC1.
6. Verify the PCI of SC2 and its neighbor.
7. Verify selected PCI is one contained in the provided PCI list but never the same as that provided to the SC2 and its neighbor.
8. Verify that RSI selected matches the index of selected PCI in the PCI list.

Expected outcome

1. Selected PCI is one from the provided PCI list but never the same as that provided to the SC2 and its neighbor.

2.17 SON.PCI_17

Title: PCI selection failure

Revision: 0.01

Description: PCI selection will fail when all available PCIs are used by direct neighbors with strong RSRP.

Test setup and procedure

PCI selection cannot find a usable PCI because all available PCIs are used by direct neighbors with strong signals.

1. Refer to the diagram for the test setup. SC 1 is the testing SC.
2. Boot up SC 2 on frequency F1 and SC 3 on frequency F1. Make sure SC 2 uses PCI 2 and SC 3 uses PCI 3.
3. Adjust VA1 and VA2 such that the received RSRP at SC 1 of SC 2 should be within the NL sensitivity range (8 dB).
4. Boot up SC 1 on frequency F1 with Network Listen enabled and provisioned PCI list of {2,3}.
5. Observe the PCI selection result.

Expected outcome

1. Verify that the PCI selection fails and SC continues to transmit with current PCI, cell continue to operate under collision.

2.18 SON.PCI_18

Title: PCI collision detection

Revision: 0.01

Description: PCI collision is detected at eNB when two-node PCI collision happens

Test setup and procedure

Verify that actual PCI collision is detected with UE moving in between the two neighboring cells.

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and same PCI.
2. Connect a UE to both SCs, via two separate variable attenuators as shown in Fig. 2.
3. Adjust VA1 to attach the UE to the test SC, and start a DL full buffer traffic.
4. Adjust both VA1 and VA2 to mimic that UE is moving away from SC 1 and moving closer to SC 2.

5. Observe that PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

Expected outcome

1. PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

2.19 SON.PCI_19

Title: PCI collision is not declared at eNB when there is no PCI collision

Revision: 0.01

Description: False alarm verification

Test setup and procedure

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and but different PCIs.
2. Connect a UE to both SCs, via two separate variable attenuators as shown in Fig. 2.
3. Adjust VA1 to attach the UE to the test SC, and start a DL full buffer traffic.
4. Adjust both VA1 and VA2 to mimic that UE is moving away from SC 1 and moving closer to SC 2.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

Expected outcome

1. PCI collision is not declared at SC 1, and no PCI reselection is triggered.

2.20 SON.PCI_20

Title: PCI collision is not declared at eNB when there is no PCI collision, for neighbor with non-colliding CRS

Revision: 0.01

Description: False alarm verification

Test setup and procedure

Verify that no false alarm when there is no PCI collision with UE moving in between the two neighboring cells for neighbor with non-colliding CRS.

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and but different PCIs, and ensure that PCIs are chosen so that SC1 and SC2 have non-colliding CRS
2. Connect a UE to both SCs, via two separate variable attenuators as shown in diagram.
3. Adjust VA1 to attach the UE to the test SC, and start a DL bursty traffic.
4. Adjust both VA1 and VA2 to mimic that UE is moving away from SC 1 and moving closer to SC 2.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

Expected outcome

1. PCI collision is not declared at SC 1, and no PCI reselection is triggered.

2.21 SON.PCI_21

Title: PCI collision is not declared at eNB when there is no PCI collision, for neighbor with colliding CRS

Revision: 0.01

Description: False alarm verification

Test setup and procedure

Verify that no false alarm when there is no PCI collision with UE moving in between the two neighboring cells with colliding CRS.

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and but different PCIs, and ensure that PCIs are chosen so that SC1 and SC2 have colliding CRS
2. Connect a UE to both SCs, via two separate variable attenuators as shown in diagram.
3. Adjust VA1 to attach the UE to the test SC, and start a DL bursty traffic.
4. Adjust both VA1 and VA2 to mimic that UE is moving away from SC 1 and moving closer to SC 2.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

Expected outcome

1. PCI collision is not declared at SC 1, and no PCI reselection is triggered.

2.22 SON.PCI_22

Title: PCI collision is not declared at eNB for a UE in poor coverage

Revision: 0.01

Description: False alarm verification

Test setup and procedure

Verify that there is no false alarm when a UE moves outside the coverage of a cell.

1. Configure the test SC (SC 1).
2. Connect a UE to the test SC via a variable attenuator.
3. Adjust the variable attenuator to attach the UE to the test SC, and start a DL full buffer traffic.
4. Adjust the variable attenuator to mimic that UE is moving slowly outside the coverage of SC 1.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

Expected outcome

1. Configure the test SC (SC 1).
2. Connect a UE to the test SC via a variable attenuator.
3. Adjust the variable attenuator to attach the UE to the test SC, and start DL full buffer traffic.
4. Adjust the variable attenuator to mimic that UE is moving slowly outside the coverage of SC 1.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

2.23 SON.PCI_23

Title: PCI collision is not declared at eNB when there is no PCI collision, with neighbor doing bursty traffic

Revision: 0.01

Description: False alarm verification

Test setup and procedure

Verify that there is no false alarm when there is no PCI collision with UE moving in between the two neighboring cells, with target cell doing bursty traffic.

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and but different PCIs.
2. Connect a UE UE0 to both SCs, via two separate variable attenuators as shown in Fig. 2. Attach another UE to SC2 and start DL bursty traffic for this UE.
3. Adjust VA1 to attach UE0 to the test SC, and start a DL full buffer traffic.
4. Adjust both VA1 and VA2 to mimic that UE0 is moving away from SC 1 and moving closer to SC 2.
5. Observe if PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.x

Expected outcome

1. PCI collision is not declared at SC 1, and no PCI reselection is triggered.

2.24 SON.PCI_24

Title: PCI collision is detected at eNB when two-node PCI collision happens, for different traffic types

Revision: 0.01

Description: False alarm verification

Test setup and procedure

Verify that actual PCI collision is detected with UE moving in between the two neighboring cells, for different traffic types.

1. Configure the test SC (SC 1) and a neighboring cell (SC 2) to have the same EARFCN and same PCI.
2. Connect a UE to both SCs, via two separate variable attenuators as shown in Fig. 2.
3. Adjust VA1 to attach the UE to the test SC, and start a skype audio session.
4. Adjust both VA1 and VA2 to mimic that UE is moving away from SC 1 and moving closer to SC 2.
5. Observe that PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.
6. Repeat steps 3 through 5 above with UE playing a youtube video and for UE downloading webpages sequentially for the duration of the test.

Expected outcome

1. PCI collision is declared at SC 1 and subsequent PCI reselection is triggered.

2.25 SON.PCI_25

Title: Random PCI selection

Revision: 0.01

Description: Prove random PCI selection

Test setup and procedure

Persistency is disabled, self-configuration enabled.

1. Configure 4 PCIs and RSIs in SC1
2. Re-boot SC1 multiple times (20x)
3. Observe selected PCIs after each bootup.

Expected outcome

1. Distribution of selected PCI is close to equal.

2.26 SON.PCI_26

Title: PCI allocation prioritize avoiding PCI collision than confusion

Revision: 0.01

Description: Verify that PCI selection picks from neighbor of neighbor PCIs rather than neighbor PCIs. Avoiding collision is more important than avoiding confusion since you can operate under confusion by asking UE to report eCGI at time of handover.

Test setup and procedure

1. Configure SC2 with PCI 200, SC3 with PCI 201, SC4 with PCI 202.
2. SC1 is neighbor of SC2 and SC3. SC4 is neighbor of SC2 and not SC1.
3. PCI 200,201,202 are configured in provisioned list of SC1.

Expected outcome

1. SC1 will be allocated PCI 202. Avoiding collision is more important than avoiding confusion since you can operate under confusion by asking UE to report eCGI at time of handover.

3 Automatic Neighbor Relation Function

3.1 SON.ANR_1

Title: UE assisted detection of new intra-frequency neighbors

Revision: 0.01

Description: Detection of a new intra-frequency neighbor by UE ANR

Test setup and procedure

Verify UE ANR for an intra-frequency neighbor. Newly detected intra-frequency neighbor should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure one neighboring cell, SC 2, to operate on frequency F1 and select PCI 2. Power up SC 2.
3. Power cycle the UE and make it camp on SC 1.
4. UE initiates a call on SC 1.
5. Adjust VA2 such that SC 2 can be detected by the UE, e.g., with a RSRP> of -95dBm.
6. Wait and observe the NRT update on SC 1, if any.
7. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2.

Expected outcome

1. New intra-frequency neighbor cell is added in the NRT. HO to this neighbor is successful with the updated NRT information.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB4 message for newly added Neighbor in NRT (optional).

3.2 SON.ANR_2

Title: UE assisted detection of new inter-frequency neighbors

Revision: 0.01

Description: Detection of a new inter-frequency neighbor by UE ANR

Test setup and procedure

Verify UE ANR for an inter-frequency neighbor. Newly detected inter-frequency neighbor should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure one neighboring cell, SC 2, to operate on a different frequency F2 and select PCI 2. Power up SC 2.
3. Power cycle the UE and make it camp on SC 1.
4. UE initiates a call on SC 1.
5. Adjust VA2 such that SC 2 can be detected by the UE, e.g., with a RSRP> of -95dBm.
6. Wait and observe the NRT update on SC 1, if any.
7. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2 with the updated NRT.

Expected outcome

1. New inter-frequency neighbor cell is added in the NRT. HO to this neighbor is successful with the updated NRT information.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB5 message for newly added Neighbor in NRT (optional).

Notes

For Inter-Frequency HO, we need to trigger A2 event. After A2, eNB will initiate A5 event.

3.3 SON.ANR_3

Title: ANR Function after power on, intra-frequency

Revision: 0.01

Description: Detection of multiple new intra-frequency neighbors

Test setup and procedure

Verify UE ANR for an intra-frequency neighbor. Newly detected intra-frequency neighbor should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure two neighboring cell, SC 2 & SC3, to operate on a same frequency F1 and select PCI 2 & PCI 3 respectively. Power up SC 2 & SC3.
3. Connect a UE to all three SCs (SC 1/2/3) via three separate variable attenuators (VA1/2/3).
4. Power cycle the UE and make it camp on SC 1.
5. UE initiates a call on SC 1.

6. Adjust VA2/VA3 such that SC 2 & SC 3 can be detected by the UE, e.g., with a RSRP of -95dBm for both SC 2 and SC 3.
7. Wait and observe the NRT update on SC 1, if any.
8. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2.
9. Repeat Step 8, but verify HO to SC 3 but with the help of VA 1 and VA 3.

Expected outcome

1. New intra-frequency neighbor cell is added in the NRT. HO to this neighbor is successful with the updated NRT information.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB4 message for newly added Neighbor in NRT (optional).

3.4 SON.ANR_4

Title: ANR Function after power on, inter-frequency

Revision: 0.01

Description: Detection of multiple new inter-frequency neighbors

Test setup and procedure

Verify UE ANR for more than one inter-frequency neighbors. Newly detected inter-frequency neighbors should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure two neighboring cells, SC 2 and SC 3, to operate on a different frequency F2 and select PCI 2 and 3, respectively. Power up SC 2 and SC 3.
3. Connect a UE to all three SCs (SC 1/2/3) via three separate variable attenuators (VA1/2/3).
4. Power cycle the UE and make it camp on SC 1.
5. UE initiates a call on SC 1.
6. Adjust VA2 and VA3 such that SC 2 and SC 3 can be detected by the UE, e.g., with a RSRP of -95dBm for both SC 2 and SC 3.
7. Wait and observe the NRT update on SC 1, if any.
8. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2 with the updated NRT.
9. Adjust VA 1 and VA 3 to mimic UE moving away from SC 1 and closer to SC 3. Verify UE handover to SC 3 with the updated NRT.

Expected outcome

1. New inter-frequency neighbor cells are added in the NRT. HO is successful with the updated NRT information.

2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB5 message for newly added Neighbor in NRT (optional).

Notes

For Inter-Frequency HO, we need to trigger A2 event. After A2, eNB will initiate A5 event.

3.5 SON.ANR_5

Title: ANR Function after power on, intra- and inter-frequency

Revision: 0.01

Description: Detection of both intra- and inter-frequency neighbors

Test setup and procedure

Verify UE ANR for both intra- and inter-frequency neighbors. Newly detected neighbors should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure neighboring cell SC 2 to operate on F1 and select PCI 2. Power up SC 2.
3. Configure neighboring cell SC 3 to operate on F2 and select PCI 3. Power up SC 3.
4. Power cycle the UE and make it camp on SC 1.
5. UE initiates a call on SC 1.
6. Adjust VA2 and VA3 such that SC 2 and SC 3 can be detected by the UE, e.g., with a RSRP> of -95dBm for both SC 2 and SC 3.
7. Wait and observe the NRT update on SC 1, if any.
8. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2 with the updated NRT.
9. Adjust VA 1 and VA 3 to mimic UE moving away from SC 1 and closer to SC 3. Verify UE handover to SC 3 with the updated NRT.

Expected outcome

1. New intra- and inter-frequency neighbor cells are added in the NRT. HO is successful with the updated NRT information.
2. Verify the newly added neighbors, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB 4 & 5 message for newly added Neighbor in NRT (optional).

Notes

For Inter-Frequency HO, we need to trigger A2 event. After A2, eNB will initiate A5 event.

3.6 SON.ANR_6

Title: UE assisted Intra-frequency ANR Function (after a handover)

Revision: 0.01

Description: Verify UE ANR detection of a new intra-frequency neighbor after a handover

Test setup and procedure

After a handover completed from eNB1 to eNB2, the UE is configured with ANR measurement configuration and performs ANR successfully of a new intra-frequency neighbor.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure one neighboring cell, SC 2, to operate on frequency F1 and select PCI 2. Power up SC 2.
3. Connect a UE to both SCs (SC 1/2) via two separate variable attenuators (VA1/2).
4. Power cycle the UE and make it camp on SC 1.
5. UE initiates a call on SC 1.
6. Adjust VA2 such that SC 2 can be detected by the UE, e.g., with a RSRP of -95dBm.
7. Wait and observe the NRT update on SC 1, if any.
8. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2 with the updated NRT.
9. Configure one neighboring cell, SC 3, to operate on frequency F1 and select PCI 3. Power up SC 3.
10. Connect the UE to SC 2 via a variable attenuator VA 3.
11. Adjust VA 3 such that SC 3 can be detected by the UE, e.g., with a RSRP of -95dBm.
12. Wait and observe the NRT update on SC 2, if any.
13. Adjust VA 2 and VA 3 to mimic UE moving away from SC 2 and closer to SC 3. Verify UE handover to SC 3 with the updated NRT.

Expected outcome

1. UE ANR is successful on SC 2 in terms of discovering SC 3 and adding to its NRT. HO from SC 2 to SC 3 is successful.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB 4 message for newly added Neighbor in NRT (optional).

3.7 SON.ANR_7

Title: UE assisted Inter-frequency ANR Function (after a handover)

Revision: 0.01

Description: Verify UE ANR detection of a new inter-frequency neighbor after a handover

Test setup and procedure

After a handover completed from eNB1 to eNB2, the UE is configured with ANR measurement configuration and performs ANR successfully of a new intra-frequency neighbor.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Configure one neighboring cell, SC 2, to operate on frequency F1 and select PCI 2. Power up SC 2.
3. Connect a UE to both SCs (SC 1/2) via two separate variable attenuators (VA1/2).
4. Power cycle the UE and make it camp on SC 1.
5. UE initiates a call on SC 1.
6. Adjust VA2 such that SC 2 can be detected by the UE, e.g., with a RSRP of -95dBm.
7. Wait and observe the NRT update on SC 1, if any.
8. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2 with the updated NRT.
9. Configure one neighboring cell, SC 3, to operate on frequency F1 and select PCI 3. Power up SC 3.
10. Connect the UE to SC 2 via a variable attenuator VA 3.
11. Adjust VA 3 such that SC 3 can be detected by the UE, e.g., with a RSRP of -95dBm.
12. Wait and observe the NRT update on SC 2, if any.
13. Adjust VA 2 and VA 3 to mimic UE moving away from SC 2 and closer to SC 3. Verify UE handover to SC 3 with the updated NRT.

Expected outcome

1. UE ANR is successful on SC 2 in terms of discovering SC 3 and adding to its NRT. HO from SC 2 to SC 3 is successful.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].
3. We can also verify the SIB 4 & 5 message for newly added Neighbor in NRT (optional).

Notes

For Inter-Frequency HO, we need to trigger A2 event. After A2, eNB will initiate A5 event.

3.8 SON.ANR_8

Title: ANR Function after power on, intra-frequency

Revision: 0.01

Description: Detection of a new intra-frequency neighbor by NL ANR

Test setup and procedure

Verify NL ANR for an intra-frequency neighbor. Newly detected intra-frequency neighbor should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Observe the NRT of SC 1 is empty. Power off SC 1.
3. Configure one neighboring cell, SC 2 (in the NL range of SC 1), to operate on frequency F1 and select PCI 2. Power up SC 2.
4. Power up SC 1
5. Note the NRT updated on SC1 with the neighbor SC2. Verify X2 status.
6. Note the NRT of SC2 is updated with the neighbor SC1.

Expected outcome

1. New intra-frequency neighbor cell is added in the NRT.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.9 SON.ANR_9

Title: ANR Function after power on, inter-frequency

Revision: 0.01

Description: Detection of a new inter-frequency neighbor by NL ANR

Test setup and procedure

Verify NL ANR for an inter-frequency neighbor. Newly detected inter-frequency neighbor should be added in NRT with eCGI of this target PCI.

1. Power up the test SC (SC 1), configure the test SC to operate on frequency F1 and select PCI 1.
2. Observe the NRT of SC 1 is empty.
3. Configure inter-frequency carrier as per frequency F2. Power off SC 1.
4. Configure one neighboring cell, SC 2 (in the NL range of SC 1), to operate on frequency F2 and select PCI 2. Power up SC 2.
5. Power up SC 1
6. Note the NRT updated on SC1 with the neighbor SC2. Verify X2 status.
7. Note the NRT of SC2 is updated with the neighbor SC1.

Expected outcome

1. New inter-frequency neighbor cell is added in the NRT.
2. Verify the newly added neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.10 SON.ANR_10

Title: NRT cleanup

Revision: 0.01

Description: Neighbor deletion due to inactivity

Test setup and procedure

Verify intra-frequency NRT entry get deleted due to inactivity.

1. Configure SC1 and SC 2 (in the NL range), to operate on frequency F1 and select PCI1 & PCI 2 respectively.
2. Power up the SC (SC 2), after SC2 booting up power up SC 1.
3. Note the NRT updated on SC1 with the neighbor SC2 and vice versa. Verify X2 status.
4. Wait set time during which there is no activity on either eNB i.e. time without any UE connected to the cells.
5. Observe the Neighbour relation is deleted.
6. Check Neighbor Deletion Statistics.

Expected outcome

1. Existing intra-frequency neighbor cell is removed from NRT.
2. Verify removal of the neighbor, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.11 SON.ANR_11

Title: NRT persistency

Revision: 0.01

Description: Demonstrate that the NRT is maintained after a power cycle

Test setup and procedure

eNB1 has multiple entries in its NRT.

- eNB1 is power cycled

Expected outcome

- NRT should be maintained after the power cycle.

3.12 SON.ANR_12

Title: Removal/noRemoval of a neighbour cell

Revision: 0.01

Description: Define the removal/noRemoval of a neighbour cell from the initial NRT (NR status: locked/unlocked)

Test setup and procedure

1. Configure SC1 and SC 2 (in the NL range), to operate on frequency F1 and select PCI1 & PCI 2 respectively.
2. Power up the SC (SC 2), after SC2 booting up power up SC 1.
3. Note the NRT updated on SC1 with the neighbor SC2 and vice versa. Verify X2 status
4. Mark SC2 as "not be removed" neighbor of SC1
5. Wait set time during which there is no activity on either eNB i.e. time without any UE connected to the cells.
6. Check the neighbor deletion statistics.

Expected outcome

1. Neighbor related should not be deleted.
2. Verify neighbor is not removed, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.13 SON.ANR_13

Title: Configuring/notConfiguring X2 between neighbors

Revision: 0.01

Description: Configuring/notConfiguring X2 between the source-neighbour cell pair (X2 status: required/notRequired)

Test setup and procedure

1. Configure SC1 and SC 2 (in the NL range), to operate on frequency F1 and select PCI1 & PCI 2 respectively.
2. Configure that X2 pair between SC1 and SC2 is not created.
3. Power up the SC (SC 2), after SC2 booting up power up SC 1.
4. Note the NRT updated on SC1 with the neighbor SC2 and vice versa. Verify X2 status.

Expected outcome

1. NRT should be updated, but X2 should not be created between SC1 and SC2.
2. Verify neighbor addition at both SC1 and SC2, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.14 SON.ANR_14

Title: Enable/disable the computation of initial NRT via ANR

Revision: 0.01

Description: Operator shall have the flexibility to enable/disable the computation of initial NRT via ANR on per-eNB basis

Test setup and procedure

Disable ANR feature; in that case NRT table needs to be created through manual configuration.

Expected outcome

Operator should have the flexibility to turn off the ANR feature

3.15 SON.ANR_15

Title: Disable X2 HO between a source-target cell pair

Revision: 0.01

Description: Initial NRT shall be able to disable X2 HO between a source-target cell pair even if X2 is established

Test setup and procedure

1. Configure SC1 and SC 2 (in the NL range), to operate on frequency F1 and select PCI1 & PCI 2 respectively.
2. Configure to disable X2 HO between SC1 and SC2
3. Power up the SC (SC 2), after SC2 booting up power up SC 1.
4. Note the NRT udated on SC1 with the neighbor SC2 and vice versa. Verify X2 status
5. Connect a UE to both SCs (SC 1/2) via two separate variable attenuators (VA1/2).Power cycle the UE and make it camp on SC 1.
6. UE initiates a call on SC 1.
7. Adjust VA2 such that SC 2 can be detected by the UE, e.g., with a RSRP of -95dBm.
8. Wait and observe the NRT update on SC 1, if any.
9. Adjust VA 1 and VA 2 to mimic UE moving away from SC 1 and closer to SC 2. Verify UE handover to SC 2.

Expected outcome

Confirm that there is S1 HO from SC1 to SC2 as X2 HO is disabled.

3.16 SON.ANR_16

Title: NRT update when cell parameters changes

Revision: 0.01

Description: Show ANR interaction updating NRT upon PCI change of target cell

Test setup and procedure

Target cell is part of the NRT but its PCI changed hence info must be updated (Same ECGI).

1. Configure SC1 and SC 2 (in the NL range), to operate on frequency F1 and select PCI1 & PCI 2 respectively.

2. Update the PCI for SC1 manually to PCI3
3. Check the NRT table of SC1 and SC2

Expected outcome

1. PCI value should be updated in the both the NRT tables.
2. Verify the updated PCI, e.g., using FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i} [S1].

3.17 SON.ANR_17

Title: X2 based NRT update

Revision: 0.01

Description: If X2 is established between cells, the neighbouring relation is mutually added

Test setup and procedure

X2 supported and configured. Persistency disabled.

1. Configure SC1 and SC2 on F1.
2. Power on SC1. Observe the NRT is empty.
3. Power on SC2 in the NL range of SC1. Observe NRT updated with SC1 neighbour. Also observe SC1 NRT updated with SC2.

Expected outcome

1. PCI value should be updated in the both the NRT tables.
2. Verify the updated PCI in FAPService.{i}.CellConfig.LTE.RAN.NeighborListInUse.LTECell.{i}.

4 Inter-Cell Interference Coordination/ Interference Management for Downlink

4.1 SON.ICIC_1

Title: Initial CER Configuration with ICIC Self configuration Disabled

Revision: 0.01

Description: Verify eNB is following CER configuration based on OAM

Test setup and procedure

1. For 1 eNB setup, boot up eNB with self-configuration disabled.
2. Bring up a UE as a CEU with DL full buffer traffic and verify that the UE uses resources corresponding to the configuration.
3. Change the SINR conditions to categorize the UE as CCU and verify it uses CCR.

Expected outcome

Verify that eNB follows CER configuration based on OAM.

4.2 SON.ICIC_2

Title: CCU and CEU configuration

Revision: 0.01

Description: Verify that a cell center user (CCU) and a cell edge user (CEU) have different resource assignments. Verify that CCU and CEU have different PDSCH power assignment

Test setup and procedure

- eNB1 is configured with ICIC.
- eNB2 is configured with ICIC and adjacent to eNB2.
- At least two UEs are in eNB1, UE1 at low path loss (high SINR, cell center) and UE2 close to the boundary with eNB2 (low SINR, cell edge user). Similarly, at least two UEs are in eNB2 in locations similar to those on eNB1 to provide interference.

1. Boot up eNB. Connect two UE's as described on eNB1.
2. Verify that UE1 experience good radio conditions (e.g., CQI >=14, rank = 2).
3. Verify that UE2, at cell edge, experience medium to poor radio conditions (e.g., CQI <= 10).

4. Start full buffer data transfer on all UEs.

Expected outcome

1. Verify UE1 is scheduled to use Cell Center PRB's
2. Verify UE2 is only schedule to use the Cell Edge PRB's.
3. Verify PDSCH power used for the two UE's
4. CCU should have lower power than CEU

4.3 SON.ICIC_3

Title: CCU to CEU adaptation

Revision: 0.01

Description: Verify that a CCU moving toward the cell edge is reconfigured when its RF condition degrades

Test setup and procedure

- eNB1 is configured with ICIC
- eNB2 is configured with ICIC and adjacent to eNB2
- Two UEs are in eNB1 and eNB2. eNB2 has one UE as cell center and other as cell edge, i.e., close to boundary with eNB1. Both UEs in eNB1 are at cell center initially.

1. Bring up eNB1 and eNB2 as specified in the initial condition.
2. Verify that UE1 and UE2 on eNB1 experience good radio conditions (e.g., CQI >=14, rank = 2).
3. Start full buffer data transfer on all UEs.
4. Move UE1 from the original radio conditions toward the cell edge radio conditions (i.e., CQI<=10, rank = 1).

Expected outcome

Verify UE1 is reconfigured from CCU to CEU as its radio conditions degrade. Note the change in PRB used for data transfer as well as allocated PDSCH power

4.4 SON.ICIC_4

Title: Hysteresis for User Categorization change

Revision: 0.01

Description: Verify frequent user categorization is avoided (e.g., due to fading)

Test setup and procedure

- eNB1 is configured with ICIC
- eNB2 is configured with ICIC and adjacent to eNB2

- At least two UEs are in eNB1, UE1 at low path loss (high SINR, cell center) and UE2 close to the boundary with eNB2 (low SINR, cell edge user). Similarly, set up two UEs in eNB2 in locations similar to those on eNB1 to provide interference.

1. Bring up eNB1 and eNB2 as specified in the initial condition.
2. Verify that UE1 experiences good radio conditions (e.g., CQI >=14, rank =2)
3. Verify that UE2, at cell edge, experience medium to poor radio conditions (e.g., CQI <=10, rank =1)
4. Start full buffer data transfer on all UE's
5. Adjust RF conditions such that UE1 moves from cell center to cell edge and back to cell center radio conditions within few hundred milliseconds (e.g., within 100 ms).

Expected outcome

Verify that UE remains categorized as CCU

4.5 SON.ICIC_5

Title: Pa update for CEU to CCU

Revision: 0.01

Description: Verify Pa update for CEU to CCU

Test setup and procedure

- eNB1 is configured with ICIC
- eNB2 is configured with ICIC and adjacent to eNB2
- At least two UEs are in eNB1, UE1 at low path loss (high SINR, cell center) and UE2 close to the boundary with eNB2 (low SINR, cell edge user). Similarly, set-up two UEs in eNB2 in locations similar to those on eNB1 to provide interference.

1. Bring up eNB1 and eNB2 as specified in the initial condition.
2. Verify that UE1 experiences good radio conditions (e.g., CQI >=14, rank =2)
3. Verify that UE2, at cell edge, experience medium to poor radio conditions (e.g., CQI <=10, rank = 1)
4. Start full buffer data transfer on all UE's
5. Move UE2 from the original radio conditions toward the cell center radio conditions (e.g., CQI >=14, rank = 2)

Expected outcome

Verify that UE2 gets classified as cell center user and new Pa value corresponding to cell center user is applied after RRC Reconfiguration message has been received.

4.6 SON.ICIC_6

Title: Pa update for CCU to CEU

Revision: 0.01

Description: Verify Pa update for CCU to CEU

Test setup and procedure

- eNB1 is configured with ICIC
- eNB2 is configured with ICIC and adjacent to eNB2
- At least two UEs are in eNB1, UE1 at low path loss (high SINR, cell center) and UE2 close to the boundary with eNB2 (low SINR, cell edge user). Similarly, set-up UEs in eNB2 in locations similar to those in eNB1 to provide interference.

1. Bring up eNB1 and eNB2 as specified in the initial condition.
2. Verify that UE1 experiences good radio conditions (e.g., CQI >=14, rank = 2)
3. Verify that UE2, at cell edge, experience medium to poor radio conditions (e.g., CQI < =10, rank = 1)
4. Start full buffer data transfer on all UE's
5. Move UE1 from the original radio conditions toward the cell edge radio conditions (e.g., CQI<10, rank = 1)

Expected outcome

Verify that UE1 gets classified as cell edge user and new Pa value corresponding to cell edge user is applied after the RRC reconfiguration message has been received.

4.7 SON.ICIC_7

Title: ICIC Configuration in presence of neighbor with no RNTP

Revision: 0.01

Description: Verify that a neighbor is not considered for ICIC if RNTP is not received

Test setup and procedure

- eNB1, eNB2 are configured to select any of the two CER partitions (colors). eNB3 is not configured to perform ICIC (and therefore no RNTP exchange).
- eNB1, eNB2 and eNB3 are neighbors.

1. Boot up eNB1.
2. Configure the eNB1 such that it can select any one of two CER partitions (colors) for ICIC.
3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of two CER partitions (colors) for ICIC.
4. Connect an UE at the cell edge of each eNB (eNB1, eNB2 and eNB3).
5. Connect another UE close to cell center of each eNB (eNB1, eNB2 and eNB3).

Expected outcome

1. Verify that RNTP messages are exchanged between eNB1 and eNB2.
2. Verify that RNTP messages are not exchanged between eNB3 and other two eNBs.
3. Verify that both eNB1 and eNB2 are configured with different CER partitions (colors), i.e., they continue to perform ICIC with each other even in presence of another eNB that does not participate in ICIC.

4.8 SON.ICIC_8

Title: Automated ICIC configuration

Revision: 0.01

Description: Verify that eNB can select an appropriate CERs (cell edge resources aka "color") for ICIC

Test setup and procedure

- eNB1, eNB2 and eNB3 are configured to select any one of three CER partitions (colors) for ICIC.
- eNb1, eNB2 and eNB3 are each other’s neighbors

1. Boot up eNB1.
2. Configure the eNB such that it can select any one of three CER partitions (colors) for ICIC.
3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of three CER partitions (colors) for ICIC.
4. Boot eNB3 such that it is a neighbor of eNB1 and eNB2 and can select any one of three CER partitions (colors) for ICIC.
5. Connect an UE at the cell edge of each eNB (eNB1, eNB2 and eNB3).
6. Connect another UE close to cell center of each eNB (eNB1, eNB2 and eNB3)

Expected outcome

1. Verify that RNTP messages are exchanged when second and third eNB are booted.
2. Verify that each of the eNBs are configured with different colors.
3. Verify that the three cell-edge UE's are allocated non overlapping PRB's based on the selected ICIC CER partition (color).

4.9 SON.ICIC_9

Title: ICIC configuration to avoid strong neighbor

Revision: 0.01

Description: Verify that eNB can select an appropriate CERs (cell edge resources aka "color") to avoid strongest neighbor for ICIC

Test setup and procedure

- eNB1, eNB2 and eNB3 are configured to select any one of two colors for ICIC.
- eNB1, eNB2 and eNB3 are each other's neighbors.
- eNB1 experiences eNB2 as strongest interferer (e.g., as measured by Network Listen or UE reports) and vice versa, while eNB3 experiences eNB2 as strongest interferer.

1. Boot-up eNB1.
2. Configure the eNB1 such that it can select any one of two CER partitions (colors) for ICIC.
3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of two CER partitions (colors) for ICIC.
4. Boot eNB3 such that it is a neighbor of eNB1 and eNB2 and can select any one of two CER partitions (colors) for ICIC.
5. Connect an UE at the cell edge of each eNB (eNB1, eNB2 and eNB3).
6. Connect another UE close to cell center of each eNB (eNB1, eNB2 and eNB3)

Expected outcome

1. Verify that RNTP messages are exchanged when second and third eNB are booted.
2. Verify that each of the eNBs selects appropriate CER partitions (colors) to manage interference with strongest interferer (i.e., eNB1 and eNB2 select different CER configurations, while eNB3 selects CER configuration different from eNB2, but same as eNB1)

4.10 SON.ICIC_10

Title: Automated ICIC Configuration - Neighbor cell disconnected

Revision: 0.01

Description: Verify that eNB can appropriately adjust its CERs (cell edge resources aka "color") if a neighboring cell is disconnected

Test setup and procedure

- eNB1 and eNB2 are configured to select any of the two colors for ICIC.
- eNB1 and eNB2 are neighbors

1. Boot-up eNB1.
2. Configure the eNB1 such that it can select any one of two CER partitions (colors) for ICIC.
3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of two CER partitions (colors) for ICIC.
4. Connect an UE at the cell edge of each eNB (eNB1 and eNB2), similarly connect a UE at cell center of each eNB.
5. Now power down eNB2 (and its served UEs).

Expected outcome

1. Verify that RNTP messages are exchanged when eNB2 is booted.
2. Verify that each of the eNBs selects different CER partitions (colors).
3. Verify that eNB1 goes back to no ICIC configuration when eNB2 is no longer operational
4. Note: The exact timeline and manner in which no ICIC configuration is achieved can be specified by the vendor.

4.11 SON.ICIC_11

Title: RNTP transmission bitmask

Revision: 0.01

Description: Verify the RNTP transmission bitmask

Test setup and procedure

eNB1 and eNB2 are configured as neighbors

1. Boot-up eNB1.
2. Configure the eNB1 such that it can select any one of two CER partitions (colors) for ICIC.
3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of two CER partitions (colors)s for ICIC.
4. Connect an UE at the cell edge of each eNB (eNB1, eNB2).
5. After some time, UE on eNB2 is disconnected such that eNB2 becomes unloaded.

Expected outcome

RNTP is sent to X2 neighbors periodically with RNTP bitmask corresponding to its CER configuration when:

1. Verify the RNTP bitmask transmitted to connected Neighbor when eNB2 is loaded.
2. Verify the RNTP bitmask transmitted to connected Neighbor when eNB2 is unloaded.

4.12 SON.ICIC_12

Title: RNTP transmission bitmask update

Revision: 0.01

Description: Verify that the RNTP bitmask is updated when the user categorization changes

Test setup and procedure

eNB1 and eNB2 are configured as neighbors

1. Boot up eNB1.
2. Configure the eNB1 such that it can select any one of two CER partitions (colors) for ICIC.

3. Boot eNB2 such that it is a neighbor of eNB1 and can select any one of two CER partitions (colors)s for ICIC.
4. Connect a UE at the cell edge and cell center of each eNB (eNB1, eNB2).
5. After some time, cell edge UE on eNB2 is disconnected such that eNB2 only has cell center user.

Expected outcome

1. Verify that RNTP is sent to X2 neighbors periodically with RNTP bitmask corresponding to CER configuration.
2. Verify that after eNB2 only has cell center user, fewer bits are set to 1 in the RNTP bitmask.

4.13 SON.ICIC_13

Title: Two User per Cell Throughput Comparison- Near Cell & Far Cell User

Revision: 0.01

Description: This is to demonstrate the gain in user throughput and cell throughput, if any, and change in distribution of throughput between near cell and far cell user with the ICIC Feature

Test setup and procedure

eNB1 and eNB2 are configured as neighbors

1. Enable ICIC feature
2. There should be full loading in the serving cell or in the Neighbor cells
3. Place 1 UE each in near cell (cell center) location in eNB1 and eNB2
4. Place 1 UE each in far cell (cell edge) location in eNB1 and eNB2
5. Perform full buffer DL test for a duration of 5 minutes by downloading data using Iperf to all the Test UEs
6. Disable ICIC feature
7. Repeat step 5.

Expected outcome

Verify that with ICIC feature, the throughput of cell edge UEs improves due to CER partitioning.

5 Frequent Handover Mitigation

5.1 SON.FHM_1

Title: Acquire initial (default) parameters

Revision: 0.01

Description: Prove that the UE accessing the cell receives the mobility parameters according to the "normal" parameter set. Event A3 configuration parameters assigned during call establishment to be observed.

Test setup and procedure

1. Bring up eNB1 with Tx power configuration providing reliable (> -80 dBm) RSRP at the UE receiver.
2. Attach a UE to the cell and observe event configuration parameters during the call setup procedure from UE logs (event A3 configuration parameters in RRC reconfiguration message.)

Expected outcome

HO parameters provisioned for the normal handover are applied.

Notes

System configuration:

1. One eNodeB in operation.
2. One UE, cabled-up.
3. FHM enabled.

5.2 SON.FHM_2

Title: Acquire initial (default) parameters during handover

Revision: 0.01

Description: Prove that UE performing handover in normal mode receive intra-frequency mobility parameters of the target cell provisioned for "normal" mode.

Test setup and procedure

1. Put two eNBs in service (on the same frequency) so that mutual neighbor relation is established between them. eNB1 received RSRP shall be ~3 dB higher than RSRP of eNB2 and >-80 dBm.
2. Attach a UE to eNB1.
3. Perform handover from eNB1 to eNB2 by attenuation changes.
4. Observe event A3 parameter configuration in the RRC reconfiguration message with Mobility Control Info (handover).

Expected outcome

Target cell event A3 parameters provisioned for the normal handover are applied.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.
4. FHM-enabled.

5.3 SON.FHM_3

Title: Acquire initial parameters per UE classification (fast moving)

Revision: 0.01

Description: Prove that UE classified as fast moving UE receives the intra-frequency mobility parameters provisioned for "fast moving" mode.

Prove that UE not classified as fast moving in the same time receives "normal" parameter set.

Test setup and procedure

1. Put four eNBs in service (on the same frequency) so that mutual neighbor relation is established between them.
2. Perform frequent handovers from eNB1 to eNB2 to eNB3 to eNB4, etc. to achieve the UE classified as fast moving UE. HO frequency should satisfy the relevant FHM conditions. UE should not go through RLF.
3. Observe target parameter configuration from RRC reconfiguration message with Mobility Control Info from eNB4 (handover).
4. Attach UE_2 to eNB1 and perform handover to eNB2.
5. Observe eNB1 event A3 configuration parameters at call setup and in the RRC reconfiguration message with Mobility Control Info (handover).

6. To verify that the eNBs involved correctly exchange the X2AP IE UE History Information > Last Visited Cell Information within the HANDOVER REQUEST message.

Expected outcome

Target cell event A3 parameters provisioned for the UE classification are applied.

Notes

System configuration:

1. Four eNodeBs with configured X2 neighbor relation on the same LTE frequency and same bandwidth.
2. Two UEs, cabled-up.
3. Attenuators to control path loss from eNBs to UE.
4. FHM-enabled.

5.4 SON.FHM_4

Title: Acquire initial (default) parameters during inter-frequency handover

Revision: 0.01

Description: Prove that UE performing inter-frequency handover in normal mode receive mobility parameters provisioned for normal inter-frequency handover.

eNB2 should be configured with different event A3 default parameters. Hence RCR during call setup on source cell and RCR for handover contain different A3 parameters as per configuration.

Test setup and procedure

1. Put two eNB in service (on different frequencies) so that mutual neighbor relation is established between them.
2. Attach a UE to eNB1 and increase attenuation of eNB1 so that the inter-frequency (IF) "normal" handover triggering conditions are fulfilled.
3. Observe the assigned mobility parameters in RRC reconfiguration message from UE logs.
   - A2 configuration during call setup procedure.
   - A5 parameters in RRC reconfiguration message after A2 MRM sent by the UE.
   - UE should not go through RLF

Expected outcome

HO parameters provisioned for the normal inter-frequency handover applied in source cell.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on different LTE frequency but same bandwidth

2. One UE, cable-up
3. Attenuators to control path loss from eNBs to UE

5.5 SON.FHM_5

Title: Acquire HO parameters per UE classification (ping-pong) and impact of ping-pong detection on non-ping-pong UE

Revision: 0.01

Description: Verify that where UE in ping-pong condition get their HO parameters adjusted, UEs that are not in Ping-pong conditions perform HO as expected, i.e., without any additional delays.

Test setup and procedure

The combination of user mobility patterns and cell coverage boundary layout can generate frequent unnecessary HOs.

- A Handover procedure is attempted and completed from a eNB (Cell 1) to eNB (Cell 2) using X2 messages.
- Shortly after the completion of the Handover procedure a secondary Handover procedure is attempted and completed from the eNB (Cell 2) back to the eNB (Cell 1).
- For the sequential handovers to be registered as a Ping-Pong the time the UE stays in the eNB (Cell 2) and eNB (Cell 1), as indicated in the X2AP IE Time UE Stayed in Cell, should be less than or equal to the Minimum Time of Stay (MTS), say 10 secs.

1. Set RF conditions for ping-pong between eNB1 and eNB2.
2. Place UE1 in the above conditions.
3. Ensure that UE1 goes through multiple handovers in the ping-pong conditions.
4. Verify that the eNB modifies the HO parameters for UE1.
5. Place UE2 in the above conditions, but with different slopes, such that ping-pong conditions are not detected for UE2, i.e., UE2 spends much more time than Minimum Time of Stay (MTS) on each cell, say 1 minute.
6. Compare the HO parameters set for UE1 and UE2.
7. eNB automatically detects ping-pongs per UE and adapts only ping-pong UE mobility params. Handover parameters for UE2 remain unchanged.

Expected outcome

eNB modifies the HO parameters only for the UE experiencing ping-pong.

Notes

For the eNB under test, the expected behavior should be known as well as the thresholds, counters, etc. that the feature relies on.

RF matrix to allow to connect multiple UEs to multiple eNBs should be used.

Verify that the eNBs involved correctly exchange the X2AP IE UE History Information > Last Visited Cell Information within the HANDOVER REQUEST message.

5.6 SON.FHM_6

Title: Continuous per UE handover adaptation

Revision: 0.01

Description: Verify that as mobility of the UE changes, so does its handover policies that are applied to it.

Test setup and procedure

Select RF conditions where a boundary between two cells is observed.

Select RF conditions where two additional cells can be detected (and HO'ed) in the vicinity of the boundary.

1. Two UEs are available and connected to the system.
2. Place UE1 in quasi stationary location, at the boundary of eNB1 and eNB2, where it performs ping-pong handovers between two cells and spends less than minimum time of stay (MTS) on each cell, say10 secs on each cell.
3. UE2 is moving between eNB1, eNB2, eNB3 and eNB4 and performs handovers in that sequence and spends the same 10 secs on each cell.
4. Verify that UE1 and UE2 have different HO parameters.
5. Start moving UE1, in the same way that UE2 was moving originally.
6. Verify that HO parameters for UE1 are modified based on this new mobility scenario.
7. Stop moving UE2, at the eNB1 and eNB2 boundary, and UE2 is quasi-stationary and performs ping-pong handovers between eNB1 and eNB2.
8. Verify that HO parameters for UE2 are modified based on this new mobility scenario.
9. Verify that HO parameters for UE1 and UE2 are uncorrelated and depend only of the UE mobility conditions.

Expected outcome

HO parameters are adapted to the UE mobility scenario.

HO parameters for each UE are uncorrelated, only depending on the UE mobility scenario.

Notes

RF matrix can be used to create the required RF conditions.

6 Mobility Robustness Optimisation

6.1 SON.MRO_1

Title: MRO – Ping-Pong mitigation

Revision: 0.01

Description: Perform Ping-Pong handover between eNB1 and eNB2. RLF shall not happen during this procedure.

Continue ping pong and observe Handover Performance (HP) indicator degrading. After MRO evaluation period a new HOP is selected. This HOP contains less handover friendly parameters.

Test setup and procedure

1. Put two eNBs in service and attach a UE to eNB1.
2. Observe assigned A3 parameters during call setup.
3. Perform frequent handovers between eNB1 and eNB2 by changing path loss.
4. Observe the parameters assigned during HO from eNB2 to eNB1.
5. Keep performing handovers as in step 2 until the sufficient number of HO attempts reached and MRO evaluation period is over.
6. Observe new event A3 parameters assigned by MRO.

Expected outcome

RCRs:

- from initial call setup, and
- after MRO Ping-Pong prevention action

contain the A3 parameters per respective provisioning.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.

6.2 SON.MRO_2

Title: MRO – Too Late HO prevention

Revision: 0.01

Description: Too late HO: A connection failure occurs in the source cell before the handover was initiated or during a handover. The UE attempts to re-establish the radio link connection in the target cell (if handover was initiated) or in a cell that is not the source cell (if handover was not initiated).

Simulate events of too late handover leading to RLF on the serving cell. Observe increment of related counters on the serving eNodeB. Repeat creating RLF on the same cell to reach the desired minimum HO count and failure ratio over the configured accumulation period (too-late HO failure rate threshold and number of handover attempts threshold).

UE classification should not change during test execution.

After RLFs on eNB1 the call should re-establish on eNB2.

MRO timers and event count parameters should be adjusted to easy test execution.

Test setup and procedure

1. UE is connected to eNB1.
2. Set path loss so that the received signal strength at UE from eNB1 is ~3 db higher than received signal strength from eNB2.
3. Set maximum attenuation on eNB1 RF path immediately to create RLF at the UE.
4. Wait for call reestablishment on eNB2.
5. Decrease attenuation of eNB1 in order to perform normal HO from eNB2 back to eNB1.
6. Verify that eNB1 increments the expected MRO counters (too late HO).
7. Repeat RFL conditions multiple times so the thresholds, e.g., too-late handover failure rate threshold, eNB1 trigger MRO action.
8. Verify from UE logs (RRC reconfiguration messages) that eNB1 adapts corresponding (A3) parameters.
9. Verify that each eNB involved correctly exchange the applicable handover information over the X2 interface in X2AP messages RLF INDICATION and HANDOVER REPORT.

Expected outcome

eNB1 adapts event A3 time to trigger and offset parameters to speed up handover execution (e.g., shorter timer, smaller offset).

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth.
2. One UE, cabled-up.

3. Attenuators to control path loss from eNBs to UE

6.3 SON.MRO_3

Title: MRO – Too Late HO prevention

History: MRO further adjust parameters if previous action did not improve bad performance.

Revision: 0.01

Description: After completing test case "MRO - Too Late HO prevention" continue the same procedure by generating too late handovers.

Observe that MRO will further adjust (e.g., reduce TTT and or offset) A3 mobility parameters according to the provisioned HO parameters available for intra-frequency mobility.

Test setup and procedure

1. Execute test case "MRO - Too Late HO prevention".
2. Observe non-default parameter set for event A3 in the serving cell. Note the HO parameters used according to provisioning.
3. Generate too late handovers again and observe the change in used HO parameters. The new HO parameters will be more handover-friendly parameters per provisioning.
4. MRO further adjust handover parameters to further relax cell change.

Expected outcome

HO parameters in use become handover-friendly is HOP-1 after first evaluation period and even more handover-friendly (e.g., with lower offset/hysteresis/TimeToTrigger/cell individual offset, etc.) after the second evaluation period.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation, on the same LTE frequency and same bandwidth.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.

6.4 SON.MRO_4

Title: MRO – Memory

Revision: 0.01

Description: Prove that MRO keeps track of handover performance of different handover configurations and selects the configuration which provides better performance and avoid the configuration with lower performance.

Test setup and procedure

1. Achieve MRO reacting on too late handover performance described in test case "MRO - Too Late HO prevention".
2. Observe the change in event A3 parameters. Identify the HO parameters from eNB provisioning used initially and used after the too-late handover prevention.
3. Create too early handover as described in "MRO - Too Early HO prevention".
4. Monitor related attempt and failure counters. Ensure that too early HO failure rate reaches a little less than or equal to previous too late failure rate.
5. Observe that MRO does not select previous HO parameters and keeps the current HO parameters which has better performance (too-early HOs are either less than or equal to too-late HOs).
6. Repeat the test in the way that too-early HO failure rate exceeds failure rate of too-late handovers by the defined margin.
7. Observe that MRO now selects previous HO parameters.

Expected outcome

Two handover configurations are assigned during this test. The final config is the same as the original one.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation, on the same LTE frequency and same bandwidth
2. Two UEs, cabled-up
3. Attenuators to control path loss from eNBs to UE

6.5 SON.MRO_5

Title: MRO – Persistency

Revision: 0.01

Description: Prove that performance metrics of each HO parameter are persisted. When the eNB reboots MRO avoid assigning HO parameter with bad performance.

UE attached to the eNB after reboot will not receive the "default" parameters as for the first bootup since during previous testing the given HO parameter was proven to have lower handover performance.

Test setup and procedure

1. Allow persistency on eNB1.
2. Attach a UE to eNB1 and observe the HO parameters assigned (event A3 parameters during call setup).
3. Perform test case "MRO - Too Late HO prevention".

4. Observe event A3 parameters.
5. Reboot eNB1.
6. Attach UE to eNB1 after bootup.
7. Observe A3 parameters assigned during call setup.

Expected outcome

HO parameters assigned to the UE before bootup and after bootup are the same. MRO used persisted HO parameters and performance metrics.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth
2. Two UEs, cabled-up
3. Attenuators to control path loss from eNBs to UE

6.6 SON.MRO_6

Title: Too Early Handover Counter

Revision: 0.01

Description: Detect too early, too late, and wrong cell handovers.

Test setup and procedure

RLF Indication is sent to target cell after it sends UE context release. Verify that the following MRO counters are updated:

- too_early_handover_with_RLF
- HOAttempt

1. UE is connected to eNB1.
2. Set path loss so that UE sends event A3 MRM for eNB2 to eNB1.
3. After successful HO to eNB2, set path loss to cause RLF immediately after UE context release is sent from eNB2 to eNB1, i.e., within Tstore_ue_context timer value. UE should re-establish on eNB1.

Expected outcome

Pass: The following counter(s) should increment accordingly:

- too_early_handover_with_RLF
- HOAttempt

X2 RLF indication sent from ENB1 to ENB2. Verify contents of RLF Indication.

Handover report sent from ENB2 to ENB1. Verify contents of Handover Report (type == HO Too Early).

Notes

System configuration:

1. Two eNodeB with configured as X2 neighbors
2. One UE, cable-up
3. Attenuators to control path loss from eNBs to UE

6.7 SON.MRO_7

Title: MRO – Too Early HO prevention

Revision: 0.01

Description: A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in the source cell.

Simulate events of too early handover from source cell.

- UE served by dominant source cell. A quickly rising pilot from a neighboring cell triggers handover.
- Shortly after the Handover procedure or during the handover (handover failure) the signal strength of the target cell decreases rapidly causing a Radio Link Failure or handover failure. The UE attempts an RRC Connection Re-Establishment on the source cell.

Based on the too early HO threshold (or too early HO failure rate threshold) and number of handover attempts threshold, reproduce the too early HO scenarios multiple times.

Test setup and procedure

1. UE is connected to eNB1.
2. Set path loss so that UE sends event A3 MRM for eNB2 to eNB1.
3. Between sending of MRM and receiving RCR message at the UE, attenuate eNB2 RF path to maximum to cause handover failure. UE will attempt re-establishment on eNB1 which causes a handover failure.
    a. If reducing attenuation did not take effect before receiving RCR, but after it, the UE performs HO with eNB2 and then goes through RLF and sends a re-establishment request on eNB1.
    b. Verify that eNB1 increment the expected MRO counters (e.g., too_early_handover, HO Attempt) repeat the too-early HO conditions multiple times, so the threshold, e.g., too-early handover threshold, for eNB1 to take action is exceeded.
    c. Verify that eNB1 automatically adapt cell parameters from RRC reconfiguration message from eNB2 with Mobility Control Info (handover) to adjust handover boundaries based on feedback of performance indicators.

Expected outcome

eNB1 adapts to the too early HO. HO parameters with higher TTT and/or offset value is selected.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth
2. Two UEs, cabled-up
3. Attenuators to control path loss from eNBs to UE

6.8 SON.MRO_8

Title: MRO Action for HO to a Wrong Cell

Revision: 0.01

Description: A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in a cell other than the source cell and the target cell.

RLF in the source cell before the HO was initiated or during HO procedure. UE re-establishes the connection in a cell different than the source cell.

- A Handover procedure is attempted from an eNB (Cell 1) to a cell in another Macro eNB (Cell 2) using X2 messages.
- Shortly after the completion of the Handover procedure a Radio Link Failure occurs leading to the UE attempting a RRC Connection Re-Establishment procedure in a different eNB (Cell 3).
- Based on the wrong cell HO threshold (or too early HO failure rate threshold) and number of handover attempts threshold, reproduce the wrong cell HO scenarios multiple times.

Test setup and procedure

1. UE is connected to eNB1.
2. Set path loss so that UE sends Event A3 MRM for eNB2 to eNB1.
3. After successful HO to eNB2, set path loss of UE->eNB2 to cause RLF after UE context release is sent is sent by eNB2 to eNB1 over X2 interface. The UE should re-establish on eNB3.
4. Verify that eNB1 increment the expected MRO counters (Wrong cell HO)
5. Repeat the RLF conditions multiple times, so the threshold, e.g., handover to wrong cell failure threshold, for eNB1 to take action is exceeded.
6. Verify that eNB1 automatically adapt cell parameters to adjust handover boundaries based on feedback of performance indicators.

Expected outcome

eNB1 adapts to the HO to wrong cell, e.g., through HO parameter modification.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth
2. One UE, cabled-up
3. Attenuators to control path loss from eNBs to UE

6.9 SON.MRO_9

Title: Prove the concept of aging

Revision: 0.01

Description: Verify that older data is given less weight than newer data.

Test setup and procedure

If a very long time has elapsed since handover parameters were evaluated, MRO will consider handover parameter evaluation/metrics in its memory with a reduced value.

1. Achieve MRO reacting on too late handover performance described in test case "MRO - Too Late HO prevention".
2. Observe the change in event A3 parameters. Identify the HO parameters from eNB provisioning used initially and used after the too-late handover prevention.
3. Create too early handover as described in "MRO - Too Early HO prevention".
4. Monitor related attempt and failure counters. Ensure that too early HO failure rate reaches a little less than previous too late failure rate.
5. Observe that MRO does not select previous HO parameters and keeps that current HO parameters which has better performance (too-early HOs are less than too-late HOs).
6. Allow a long time to pass, e.g., aging to occur.
7. Repeat "MRO – Too Early HO prevention" with the same fewer number of too-early handovers rather than too-late handovers.

Expected outcome

After a long time, MRO will change HO parameters due to aging of too-late handovers failure rate.

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on the same LTE frequency and same bandwidth
2. One UE, cabled-up
3. Attenuators to control path loss from eNBs to UE

6.10 SON.MRO_10

Title: MRO – Too Late HO prevention – inter-frequency

Revision: 0.01

Description: Prevention of too late HO

Test setup and procedure

Too late HO: A connection failure occurs in the source cell before the handover was initiated or during a handover. The UE attempts to re-establish the radio link connection in the target cell (if handover was initiated) or in a cell that is not the source cell (if handover was not initiated).

Simulate events of too late handover leading to RLF on the serving cell. Observe increment of related counters on the serving eNodeB. Repeat creating RLF on the same cell to reach the desired minimum HO count and failure ratio over the configured accumulation period (too-late HO failure rate threshold and number of handover attempts threshold).

After RLFs on eNB1 the call should re-establish on eNB2.

MRO timers and event count parameters should be adjusted to easy test execution.

1. UE is connected to eNB1 on frequency one. eNB2 is configured on frequency two. Good received RSRP from both cells.
2. Set path loss of eNB1 so that event A2 gets triggered.
3. After MRM for event A5 is sent, change the attenuation of eNB1 to maximum to create RLF at the UE.
4. Wait for call reestablishment on eNB2.
5. Make UE move back to eNB1.
6. Verify that eNB1 increment the expected MRO counters (too late HO).
7. Repeat RLFs multiple times, so that the thresholds, e.g., too late handover threshold, eNB1 trigger MRO action.
8. Verify from UE logs (RRC reconfiguration messages) that eNB1 adapts corresponding (A2, A5) parameters.
9. Verify that each eNB involved correctly exchange the applicable handover information over the X2 interface in X2AP messages RLF INDICATION and HANDOVER REPORT.

Expected outcome

eNB1 adapts event A2 and A5 time to trigger and threshold parameters to speed up handover execution (shorter timer, higher threshold).

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on different LTE frequency but same bandwidth.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.

6.11 SON.MRO_11

Title: MRO – Too Early HO prevention – inter-frequency

Revision: 0.01

Description: MRO – Too Early HO prevention

Test setup and procedure

A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in the source cell.

Simulate events of too early handover from source cell.

- UE served by dominant source cell. RSRP of the serving cell quickly degrade while the target cell RSRP stays low but sufficient for IF handover.
- Shortly after the Handover procedure or during the handover (handover failure) the signal strength of the target cell decreases rapidly causing a Radio Link Failure. The RSRP of the source cell is again sufficient (above IF handover thresholds). The UE attempts an RRC Connection Re-Establishment on the source cell.

Based on the too early HO threshold (or too early HO failure rate threshold) and number of handover attempts threshold, reproduce the too early HO scenarios multiple times.

1. UE is connected to eNB1.
2. Set path loss so that UE sends Event A2 and event A5 MRM for eNB2.
3. Between sending of MRM and receiving RCR message at the UE, attenuate eNB2 RF path to maximum to cause handover failure. UE will attempt re-establishment on eNB1 with cause radio link failure.
    a. If reducing attenuation did not take effect before receiving RCR, but after it, the UE will perform an HO and go through RLF and a re-establishment request on eNB1.
    b. Verify that eNB1 increment the expected MRO counters: too_early_handover, HO Attempt.
    c. Repeat the RLF conditions multiple time, so that the threshold (e.g. too early handover threshold) for eNB1 to take action is exceeded.

Expected outcome

eNB1 adapts event A2 and A5 time to trigger and threshold and/or cell individual offset parameters to delay inter-frequency handover execution (e.g., longer timer, higher threshold).

Notes

System configuration:

1. Two eNodeB with configured X2 neighbor relation on different LTE frequency but same bandwidth.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.

6.12 SON.MRO_12

Title: MRO inter-frequency – HO to a Wrong Cell prevention – inter-frequency

Revision: 0.01

Description: MRO – HO to a Wrong Cell prevention

Test setup and procedure

A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in a cell other than the source cell and the target cell.

RLF in the source cell before the HO was initiated or during HO procedure. UE re-establishes the connection in a cell different than the source cell.

- A Handover procedure is attempted from eNB1 to eNB2 using X2 messages.
- Shortly after the completion of the Handover procedure, a Radio Link Failure occurs leading to the UE attempting a RRC Connection Re-Establishment in a different Cell eNB3.
- Based on the wrong cell HO threshold (or too early HO failure rate threshold) and number of handover attempts threshold, reproduce the wrong cell HO scenarios multiple times.

1. UE is connected to eNB1.
2. Set path loss so that UE sends Event A2 and A5 MRM for eNB2. Increase path loss of eNB1 in parallel.
3. After successful HO to eNB2, set path loss of eNB2 to cause RLF after UE context release is sent by eNB2 to eNB1 over X2 interface. The UE should re-establish on eNB3**.**
4. **V**erify that eNB1 increment the expected MRO counters (Wrong cell HO)
5. Repeat the RLF conditions multiple time**s**, so the threshold, e.g.**,** handover to wrong cell failure rate threshold, for eNB1 to take action is exceeded**.**
6. **V**erify that eNB1 automatically adapt cell parameters to adjust handover boundaries based on feedback of performance indicators.

Expected outcome

eNB1 adapts event A2 and A5 time to trigger and/or cell individual offset parameters for inter-frequency handover execution.

Notes

System configuration:

1. Three eNodeBs with configured X2 neighbor relation and with the same bandwidth; eNB1 and eNB3 on frequency one, eNB2 on frequency two.
2. One UE, cabled-up.
3. Attenuators to control path loss from eNBs to UE.

6.13 SON.MRO_13

Title: MRO trigger

Revision: 0.01

Description: MRO reacts only after collection of a certain minimum number of handover events and after certain minimum amount of time.

Test setup and procedure

Configure minimum number of handover events and after certain minimum amount of time using cSON-OAM.

1. Simulate event of too-early handover leading to RLF or HO failure on the serving cell with a UE.
2. Observe increment of related MRO counters on the serving eNodeB.
3. Repeat creating too-early handover events to reach the HO count not sufficient to trigger MRO feature.

Expected outcome

MRO should not update any HO parameters.

6.14 SON.MRO_14

Title: MRO – Persistency, Change of TX Power

Revision: 0.01

Description: MRO reset upon significant TX power change

Test setup and procedure

1. Allow persistency on eNB1.
2. Attach a UE to eNB1 and observe HO parameters assigned (event A3 parameters during call setup) Perform test case "MRO – Too Late HO prevention".
3. Observe event A3 parameters.
4. Release the call.
5. Change eNB1 Tx Power significantly so that the delta is greater than the allowed Tx power change for MRO, if any.
6. Attach UE to eNB1.
7. Observe A3 parameters assigned during call setup.

Expected outcome

HO parameters observed in step 7 are not the same as observed in step 3, but are the same as HO parameters during first bootup

A SON Feature Background

A.1 PCI selection and conflict resolution

A.1.1 Scope

This chapter describes the SON features of PCI Selection and the Conflict Resolution feature for small cells. Recommendations on interactions of the feature with OAM/Centralized SON (cSON) are also provided for end-to-end interworking in multi-vendor SON deployments.

A.1.2 Executive summary

PCI selection and conflict resolution are SON functions that select a PCI value for the small cell to use. The desired PCI should not collide with neighboring cells (Figure A-1) or *confuse* with the neighbor's neighboring cells (Figure A-2). This SON function works under the control of Operations, Administration, and Maintenance (OAM) (Figure A-3). Note that the entity labeled as OAM-CSON in Figure A-3 can adjust the configuration and input of the PCI selection and confliction resolution functions described here, but generally the latter does not depend on quick interaction with a centralized SON (cSON) that might make frequent changes. SON PCI selection and conflict resolution manage to operate with the provisioned set of PCIs with minimum or no intervention from the operator. The 3GPP framework for PCI selection is described in Section 22.3.5 of [S9].

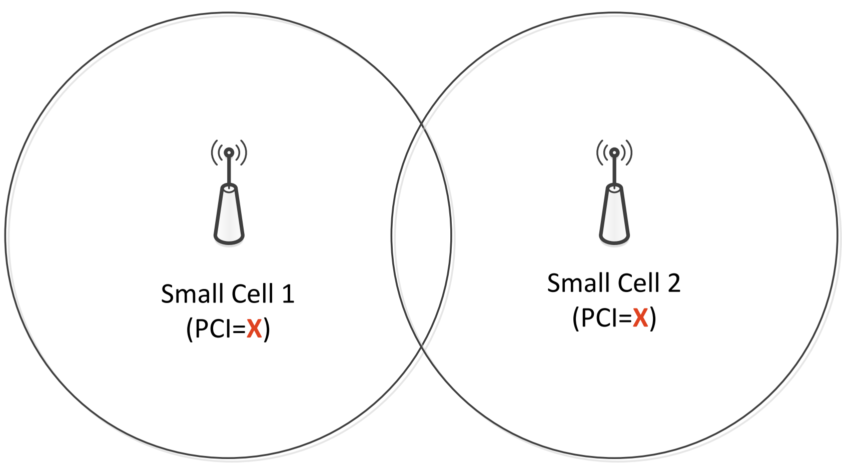


Figure A-1 PCI collision problem

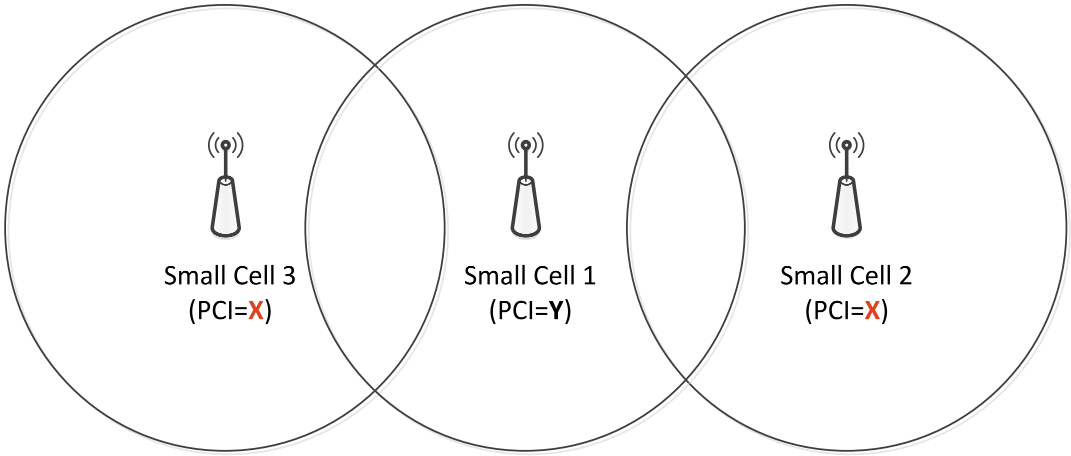


Figure A-2 PCI confusion problem

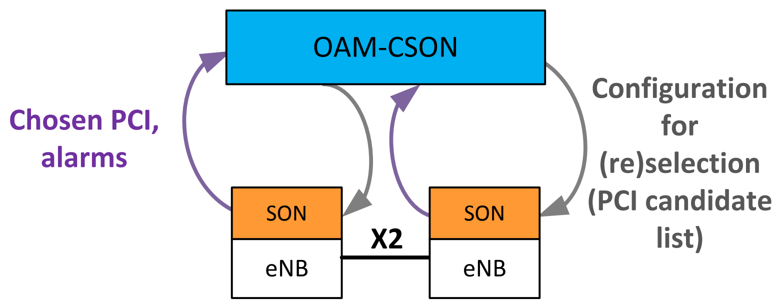


Figure A-3 PCI selection between SON and OAM

The PCI selection function selects a PCI for the Small Cell (SC) to use at small cell power-up or later on OAM command. During runtime, it reselects a new value if PCI collision or confusion is encountered or if requested by OAM. The PCI selection module also consists of PCI collision and confusion detection and resolution functions that are needed in a dense small cell deployment. PCI collision occurs when the serving cell's PCI is the same as that for one of its neighbors. PCI confusion occurs when a small cell detects that two of its neighboring small cells are using the same PCI.

The feature selects a suitable PCI from a set of PCIs provisioned by OAM. The selected PCI is reported back to the OAM. The PCI selection algorithm uses Network Listen (NL) based measurements and Neighbor Relation Table (NRT) information in the PCI selection process. Persisted PCI between small cell reboots is re-used when appropriate. Without NL support, the SC solution uses a randomly selected PCI from the available set of PCI values. If NL is available, NL-detected PCIs are removed from the available set of PCI values. Co-channel neighbors' PCIs are also removed from the candidate PCI list, and PCI is then selected randomly from the remaining PCIs.

The PCI selection feature relies on the persistency module. The *persistency* module decides, upon cell power-up, whether the previous configuration can be potentially re-used or a new configuration is needed. This is important particularly in a dynamic small cell deployment in which change of small cell locations or frequent node power-down/up can happen. In scenarios where the location of the small cell and the surrounding RF conditions have not changed after cell power-up, it is beneficial to re-use the configuration prior to previous cell power-down, with some sanity checks. On the other hand, if the small cell has moved to a different location (e.g., the owner of the small cell moves to a new house) after power-down, the small cell should correctly recognize this and start a new configuration, instead of re-using the obsolete one. Persistency determination relies on inputs such as geographical location and system time.

The following functions and operations should be supported in the SON PCI selection and conflict resolution features.

- PCI for SC operation can be selected from a PCI list provisioned by OAM. If a single PCI value is provisioned, this PCI will be selected.
  [test example: SON.PCI_3, SON.PCI_4, SON.PCI_25]
- PCI selection/reselection function uses inputs from the following functionality (if available and enabled):
  - NL-based measurements
  - NRT
  - Persistency

  [test example: SON.PCI_1, SON.PCI_2, SON.PCI_5, SON.PCI_6 - SON.PCI_11, SON.PCI_16, SON.PCI_17]
- PCI reselection and configuration by OAM at run-time is supported.
  [test example: SON.PCI_3]
- PCI collision detection and resolution can be enabled or disabled. The PCI collision detection and resolution rely on the following:
  - Network listen measurements
  - Physical Layer/Media Access Control (PHY/MAC)

  [test example: SON.PCI_18 - SON.PCI_24, SON.PCI_26]
- PCI collision detection and resolution uses inputs from following functionality:
  - Handoff status to each neighbor in NRT
  - X2-releated messages

  [test example: SON.PCI_12 - SON.PCI_15]
- PCI collision and confusion statistics are collected and available for performance monitoring

A.1.3 OAM parameters

The OAM configuration parameters for the PCI selection include the set of candidate PCI values available on the operating frequency as well as the operating frequency for the small cell.

The SON reporting parameters for the PCI selection include the selected PCI, alarms for PCI selection failure, PCI confusion, and PCI collision.

A.1.4 Feature scenarios

Several selected scenarios are discussed in the following subsections.

PCI selection

In SON, if self-configuration is not enabled and more than one PCI value is configured, the small cell uses the first value in the list for its operation.

If self-configuration is enabled, there are the following feature scenarios:

- If a single PCI is provisioned, PCI in use is set to the OAM-configured value without going through any selection algorithm.
- If Persistency is disabled, or is enabled but decides a new configuration is needed, NL is enabled and co-channel Long-Term Evolution (LTE) neighbors are discovered by NL, and more than one PCI value is configured.

  The small cell removes the detected PCIs by NL from the configured PCI list, and picks a PCI randomly from the remaining list for its operation.
  [test example: SON.PCI_1]
- If Persistency is enabled, NL is enabled, and more than one PCI value is configured:
  First the small cell will remove the detected PCIs by NL and other co-channel PCIs of the persisted NRT from the configured PCI list. Then, if the persisted PCI is in the remaining configured PCI list, the small cell picks the persisted PCI for its operation; otherwise, the small cell picks a PCI randomly from the remaining list of PCIs for its operation.
  [test example: SON.PCI_4]
- OAM can trigger PCI selection/re-selection by explicitly changing the provisioned PCI list.
  [test example: SON.PCI_3]

If PCI selection fails in these feature scenarios due to empty available PCI list, an alarm will be sent to OAM indicating failure in selecting a valid PCI. Otherwise, after a PCI is successfully selected, it will be reported to OAM.

[test example: SON.PCI_17]

PCI confusion detection and resolution

PCI confusion can be detected in the following feature scenarios.

- The SON PCI selection and conflict resolution feature monitors Handoff (HO) status to each neighbor in NRT.

  If a neighbor experiences high handover (HO) failure rates with enough HO attempts, the feature will trigger an ECGI reading for this PCI. If different ECGIs are reported, PCI confusion is declared.

  [test example: SON.PCI_12]
- The SON PCI selection and conflict resolution feature also checks all incoming X2-releated messages, including X2 Setup Request, X2 Setup Response, and X2 eNB Configuration Update, to look for potential PCI confusion.

  This can happen because either the direct neighbor has the same PCI as one other known neighbor in NRT, or the serving cell’s PCI is the same as one direct neighbor’s neighbor. If this is found, PCI confusion is declared.

[test example: SON.PCI_13]

If PCI confusion is declared, an indication is sent to OAM and the confusion counter is increased by one. Once the serving cell decides that it has more than one neighboring cells on the same frequency that use the same PCI, it will send X2 messages to these neighboring cells to trigger PCI confusion resolution. On the receiving end, once a serving cell decides, based on the X2 messages it receives, that its PCI collides with one direct neighbor's neighbor, it shall trigger the PCI reselection procedure (with some delay).

PCI collision detection and resolution

PCI collision detection using SON PCI collision detection feature, that monitors UE PHY/MAC statistics, shall be supported. With this feature, PCI collision can be detected when a UE with downlink traffic is in the overlapping area of the serving cell and cochannel neighboring cell that has the same PCI as the serving cell. The SON PCI collision detection feature monitors UE PHY/MAC statistics, to determine possible PCI collision. Also, SON PCI collision detection can monitor the UE Radio Link Failure (RLF) reports and the Radio Resource Control (RRC) re-establishment messages to detect possible PCI collision, though this typically requires Rel 10 UEs.

When a PCI collision is declared, PCI collision counter will be incremented and an event indication will be sent to OAM to notify the PCI collision. The subsequent PCI reselection can be triggered locally by SON because of this collision declaration or by OAM.

[test example: SON.PCI_18, SON.PCI_24]

A.2 Automatic neighbor relation

A.2.1 Scope

This chapter describes the Automatic Neighbor Relation (ANR) feature for small cells. Recommendations on interactions of the ANR feature with OAM/cSON are also provided for end-to-end interworking of the ANR feature in multi-vendor SON deployments.

A.2.2 Executive summary

The ANR SON function builds and manages the Neighbor Relation Table (NRT). The objective of ANR feature is to relieve the operator from the burden of manually managing Neighbor Relations (NR). The 3GPP framework for ANR is described in Section 22.3.2a of [S9].

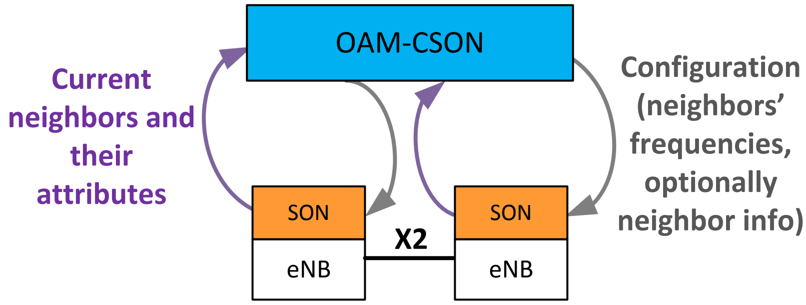


Figure A-4 PCI selection between SON and OAM

The following functions are associated with the SON ANR feature:

- Build and maintain NRT for intra/inter-frequency E-UTRAN neighbors and inter-Radio Access Technology (RAT) neighbors.
  [test example: SON.ANR_1 - SON.ANR_17]
- Discover neighbors using the following methods:
  - Network listen measurements
    [test example: SON.ANR_1 - SON.ANR_7]
  - UE measurement reports (periodic and event based)
    [test example: SON.ANR_8 - SON.ANR_9]
  - Messages exchanged over X2 interface
    [test example: SON.ANR_17]
- Manage neighbor relations in the NRT through neighbor management functions including, but not limited to, the following:
  - Addition and deletion of neighbors
    [test example: SON.ANR_10 - SON.ANR_12]
  - Updates to the neighbor relation fields
    [test example: SON.ANR_16]
- OAM can configure the SON ANR feature with an initial list of neighbors; OAM can also make updates to NRT (add/update/delete) at run-time.
  [test example: SON.ANR_13 - SON.ANR_14]
- Persistence of NRT and its reuse upon reboot if persistency conditions are met. The persistency feature will be discussed separately.
  [test example: SON.ANR_11]
- ANR related statistics can be collected and made available for performance monitoring.
  [test example: SON.ANR_6, SON.ANR_7, SON.ANR_13, SON.ANR_14]

A.2.3 Feature description

Neighbors can be discovered by NL, UE ANR, or X2.

NL-assisted neighbor discovery

NL-assisted neighbor discovery is performed during bootup. The algorithm can be divided into two steps: (1) add or update the NRT based on NL results; and (2) set up X2 connection and further update NRT.

First, NL is invoked on each of the neighbor discovery carriers, which are provisioned by OAM via the idle mode mobility parameters for inter-frequency neighbors. NL measurement results include detected cells’ PCIs, Reference Signal Received Power/Reference Signal Received Quality (RSRP/RSRQ) measurements, and Master Information Block, System Information Block (MIB/SIB) decoding. Then, for each reported PCI, the ANR feature determines if this PCI already exists in the NRT on the same carrier. If so, the ANR feature updates the entry with the latest measurement. Otherwise, neighbor discovery creates a new entry for this neighbor and adds to NRT.

Second, the ANR feature proceeds with X2 set up. This involves the standard X2 setup procedure. Once X2 is connected, ANR will inform all X2-connected neighbors of the updated

NRT via the eNB configuration update message. Updated NRT is also sent to OAM and Radio Resource Management (RRM).

UE-assisted neighbor discovery

The overall UE-assisted neighbor discovery can be divided into three steps: (1) ANR configuration; (2) neighbor discovery; and (3) set up X2 connection and update NRT. Step 3 is the same as in the section NL-assisted neighbor discovery.

The main task of ANR configuration is to determine the UE measurement configuration and send it to the RRM so that RRM can configure UEs for measurement reporting. The ANR configuration includes two modes—aggressive and normal. These two modes are UE ANR internal operation states and refer to using different sets of event thresholds for UE ANR measurement. The ANR feature switches between these two modes periodically. ANR uses a specific A3 event for intra-frequency ANR reporting, and A4 event for inter-frequency ANR reporting. In aggressive mode, the ANR configuration parameters are set such that UEs are more likely to satisfy the reporting conditions and thus report neighboring cells than in normal mode. For example, for intra-frequency UE ANR, a low A3 threshold is configured in the UE in aggressive mode so that UE will report neighboring cell whenever it can be acquired, while in normal mode, a high A3 threshold is configured so that UE reports neighboring cell only in cell edge condition. In general, it is RRM's responsibility to create and maintain UE measurement related entities, including measurement object, reporting criterion, and measurement identity for each frequency, for ANR purposes. RRM is also responsible to configure measurement gaps and Discontinuous Reception (DRX) for ANR purposes.

After the UE has been configured for ANR related measurement, RRM waits for the UE to report neighbors in response to the ANR configuration. Once such a report is received at RRM, it is forwarded to ANR for processing. The ANR feature extracts the reported PCI and determines if it is already in NRT on this carrier. If it is an unknown neighbor, ANR proceeds to request ECGI report for this new PCI by the same UE. This is accomplished via RRM/Radio Resource Control (RRC) procedure in modifying the ANR configuration to the target PCI and sending to the UE. Then ANR/RRM again waits for UE report. Once the UE measurement report on the target PCI is received, ANR extracts the ECGI information and adds this newly detected cell into the NRT.

If NRT is full and a new neighbor appears, it will not be added to the NRT. If the maximum number of X2 links is reached, no new X2 will be setup.

X2-assisted neighbor discovery

If a neighboring eNB attempts an X2 connection setup with the cell, it is automatically added to the NRT, and the information about this neighbor and its neighbors is used to create the corresponding NRT item.

Inactivity timer based neighbor removal

For a neighbor that is added to the NRT, a time stamp is added/updated to record any activity that involves this neighbor. Such activities include UE report, NL detection, or any X2 messages to/from this neighbor.

If there has been no activity for a given neighbor for a time period that is longer than a configurable threshold, this neighbor will be removed from the NRT by SON.

A.2.4 OAM parameters

The OAM configuration parameters for ANR include the neighbor's frequencies (and the air interface used for inter-Radio Access Technology (RAT) neighbors).

The ANR reports back its NRT to OAM when the initial NRT is formed or when it is later updated.

A.3 Mobility robustness optimization and frequent handover mitigation

A.3.1 Scope

This chapter describes the Mobility Robustness Optimization (MRO) SON feature and frequent handover mitigation for small cells. It also provides scenarios for using the MRO feature, and describes requirements for the interworking of macros and small cells supporting the MRO feature. Recommendations on interactions of the MRO feature with OAM/cSON are also provided for end-to-end interworking of the MRO feature in multi-vendor SON deployments.

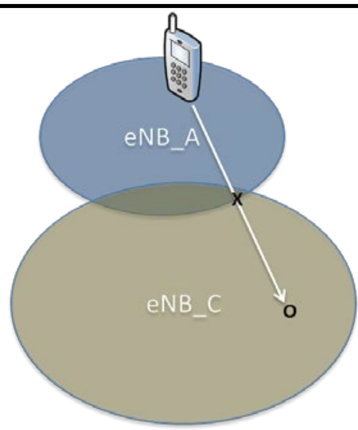
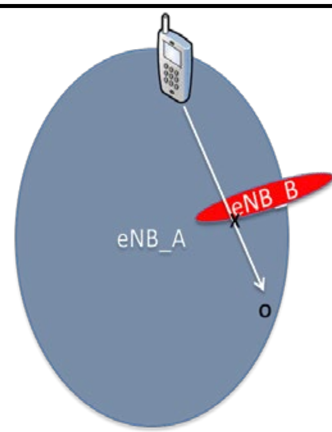
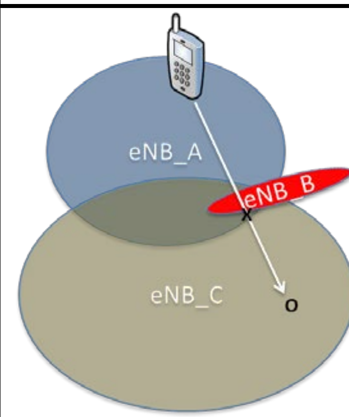
A.3.2 Feature executive summary

The MRO is a SON function that enables detection and correction of intra-LTE handover-related failures between cells. The 3GPP framework for MRO relies on support of X2 interface between the cells and is described in Section 22.4.2 of [S9].

MRO categorizes connection failures as failures due to too-early handovers or too-late handovers, or handover to wrong cell. These problems are explained in Table A-1.

Table A-1 Description of connection failures detected by MRO

Connection failure	Too-late handover	Too-early handover	Handover to wrong cell
Description	A connection failure occurs in the source cell before the handover was initiated or during a handover. The UE attempts to re-establish the radio link connection in the target cell (if handover was initiated) or in a cell that is not the source cell (if handover was not initiated).	A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in the source cell.	A connection failure occurs shortly after a successful handover from a source cell to a target cell or during a handover. The UE attempts to re-establish the radio link connection in a cell other than the source cell and the target cell.
Example Scenario	UE mobility is more aggressive than what the HO parameter settings allow for.	When the UE exits the island of coverage of the target cell, it cannot acquire the target cell anymore and the HO fails.	Cell Individual Offset (CIO) or event/frequency offset or Time to Trigger (TTT) handover parameters are set incorrectly, causing handover to wrong cell.

Connection failure	Too-late handover	Too-early handover	Handover to wrong cell
Illustration			
Detection of Connection Failure type at Source eNB (eNB_A), when more than one eNB is involved, after UE makes RRC re-establish-ment attempt*	eNB_C sends RLF Indication to eNB_A	eNB_A sends RLF Indication to eNB_B and receives Handover Report from eNB_B with 'Too-Early Handover' indication	eNB_C sends RLF Indication to eNB_B; eNB_B sends Handover Report" to eNB_A indicating 'Handover to Wrong Cell'
Legend	**X** = RLF **O** = Connection re-established		

* The detection of the connection failure events, when involving more than one eNB, is enabled by the RLF Indication and Handover Report procedures executed over X2 interface.

After detection of connection failures, MRO adjusts handover parameters such as event offset, thresholds, and TTT to fix the failures.

A.3.3 Feature description

MRO SON function works under the control of cSON/OAM (see Figure A-5). It manages to operate with the provisioned sets of handover parameters with minimum or no intervention from the operator.

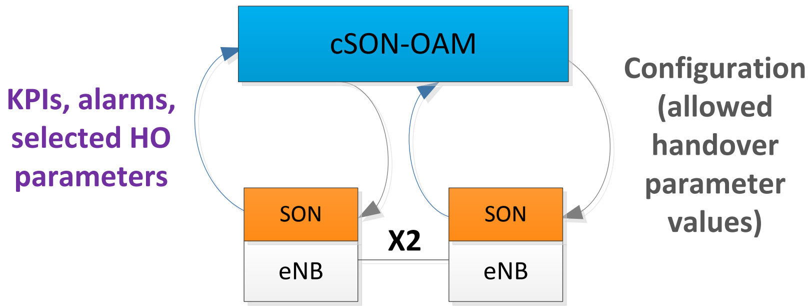


Figure A-5 MRO SON and cSON-OAM interaction

The MRO algorithm is executed separately for intra-frequency handovers and/or inter-frequency handovers, as per the configuration from cSON/OAM.

The MRO feature selects initial handover parameters based on cSON-OAM provisioning. It then monitors subsequent successful and unsuccessful handover events to adjust the selected handover parameter values to improve handover failures and handover performance. The adjustment of handover parameters is done within the limits specified by cSON-OAM provisioning through the allowed handover parameter values. Note that it is expected that cSON will set the limits of MRO algorithm by setting the allowed handover parameter values during MRO initialization. MRO will then autonomously change handover parameter values within the allowed set based on the observed handover performance and its distributed algorithm, running on each eNB, to improve performance.

Whenever MRO changes/adjusts its handover parameters, it informs cSON-OAM of the new selection. It also persists its selection of parameters between reboots when appropriate.

In addition to correcting handover failures, MRO can implement handover optimization function, where it tries to prevent unnecessary ping-pong handovers. This can be achieved by using “UE history information” Information Element (IE) [S10] to detect ping-pong handovers and making changes to handover parameters to mitigate them.

To enhance performance of MRO algorithm further, another SON algorithm, Frequent Handover Mitigation (FHM), can be enabled to allow MRO to operate on UEs with different mobility requirements differently.

The **Frequent Handover Mitigation (FHM)** feature enables mitigation of frequent undesired handovers of a UE by first classifying the UE based on its mobility pattern and then taking action based on its classification. FHM uses “UE history information” Information Element (IE) [S10], which is passed during the handovers from one cell to the other, to identify frequent handovers (using the time spent by the UE on the past serving cells) and to classify user as:

- **Ping-pong** – When a cell identity is repeated sufficient times in recent UE history
- **Fast-moving** – When cell identities of past serving cells are unique in recent UE history

In the case that a UE is experiencing ping-pong handovers, FHM adjusts handover parameters such as offset, hysteresis, and time-to-trigger of the UE to mitigate its ping-pong handovers. Alternatively, if fast-moving handovers are being experienced by the UE, FHM either initiates an inter-frequency handover of the UE to macro-layer or provides the UE with handover friendly parameters to avoid potential RLFs.

[test example: SON.FHM_3, SON.FHM_5, SON.FHM_6]

If UE handovers are infrequent (for example, in case of slow moving UEs), FHM does not take any action and lets UE use normal handover parameters.

[test example: SON.FHM_1, SON.FHM_2, SON.FHM_4]

It is important to note that FHM takes action on a per UE basis. It is possible for an eNB to provide one set of handover parameters to its serving UE-1, while another set of handover parameters to its serving UE-2.

[test example: SON.FHM_3, SON.FHM_5, SON.FHM_6]

While FHM focuses on classifying and acting on incoming users, MRO focuses on monitoring outgoing handover performance of UEs. Since an eNB is expected to serve different types of UEs (for example, fast moving UEs and slow moving UEs), trying to come up with one set of handover parameters that would work for all kind of UEs may not be the best approach. The problems faced by fast moving UEs could be very different from the problems faced by slow moving UEs. For example, fast moving UEs served by an eNB may have too-late handover issue with its neighboring cells whereas slow moving UEs served by the same eNB may have more of a ping-pong issue with its neighboring cells. Allowing MRO to monitor and optimize handover parameters for different types of UE mobility categories separately, therefore, can enhance performance. Enabling of FHM helps in categorization of UEs based on their mobility and hence, allows MRO operation to be per UE mobility category, which is more optimized.

In this document, we focus our discussion on MRO SON feature implemented on Small Cells (SCs), which works on correcting LTE handover related failures between small cells and/or between small cells and macrocells. The following functions and operations are supported in the SON MRO feature:

- Initial handover parameters are selected by MRO based on cSON-OAM provisioning.

  [test example: SON.FHM_1 - SON.FHM_4]

- MRO works to optimize both intra-frequency and inter-frequency handovers.

  [test example: SON.MRO_2 - SON.MRO_3 - SON.MRO_6 – SON.MRO_8 - SON.MRO_17 - SON.MRO_19]

- MRO uses the following X2 messages to detect handover failures (i.e., too-late handover, too-early handover and handover to wrong cell):
  - RLF indication
  - Handover report

  [test example: SON.MRO_2 - SON.MRO_3, SON.MRO_6 - SON.MRO_8, SON.MRO_17 - SON.MRO_19]

- MRO adjusts intra-frequency and inter-frequency handover parameters at a source cell based on the corresponding successful and unsuccessful handover events. MRO computes handover failure rate based on these events to understand the magnitude of the problem.

  [test example: SON.MRO_2 - SON.MRO_3, SON.MRO_6 - SON.MRO_8, SON.MRO_17 - SON.MRO_19]

- MRO adjustment of intra-frequency handover parameters includes adjustment of Event A3 offset and time to trigger value. Adjustment of inter-frequency handover parameters includes parameters of Event A1, A2, A4, and A5 along with their time to trigger values. CIO parameters may also be adjusted. The allowed values for adjustment are provisioned through cSON-OAM.

  [test example: SON.MRO_1 - SON.MRO_3, SON.MRO_6 - SON.MRO_8, SON.MRO_17 - SON.MRO_19]

- MRO uses *UE History Information* the Information Element (IE) received during handover preparation to determine ping-pong handovers.
  [test example: SON.MRO_1]

- MRO, additionally, adjusts intra-frequency and inter-frequency handover parameters at a source cell based on ping-pong handover events. However, this adjustment has a lower priority than the adjustment for handover failures.
  [test example: SON.MRO_1]

- MRO uses the FHM algorithm, which uses UE History Information IE to categorize UE mobility, for more optimized MRO operation. When FHM is enabled, MRO runs independently and separately for each UE mobility category to fix problems of each category separately. When FHM is disabled, MRO assumes common UE category for all UEs in a cell and runs for that common UE mobility category.

- MRO remembers handover performance/handover failure rate of all previously applied handover parameters to avoid selecting the bad parameters again.
  [test example: SON.MRO_4]

- MRO uses persistence to remember its learning of handover performance/handover failure rate and selection of handover parameters after reboot.
  [test reference: SON.MRO_5]

- Since the RF environment around SCs may change with time, MRO feature employs aging mechanism to gradually make the learning of handover performance/handover failure rate obsolete for previously applied handover parameters.
  [test example: SON.MRO_9]

- MRO employs hysteresis (or margin) and filtering mechanisms to avoid frequent changing of handover parameters.
  [test example: SON.MRO_4]

- To avoid reacting prematurely, MRO reacts only after collection of a certain minimum number of handover events and after certain minimum amount of time. These requirements are provisioned through cSON-OAM.
  [test example: SON.MRO_13]

A.3.4 Feature scenarios

Several selected MRO scenarios are discussed in this section.

Selection of handover parameters at bootup

MRO takes part in the selection of handover parameters at boot-up only if it is enabled. If MRO is disabled, cSON-OAM configures the handover parameters directly.

MRO can be enabled/disabled independently for intra-frequency and inter-frequency handovers. That is, it is possible to run MRO for either intra-frequency or inter-frequency handovers only.

- If Persistency is disabled, or persistency check fails (for example, if SC location is changed):

  MRO selects its initial handover parameters based on default values provided by cSON-OAM. MRO also resets its database.

- If Persistency is enabled and persistency check passes:

  MRO uses its persistency database to select its last used handover parameters. MRO retains its database and any updates are made on top of it.

  [test example: SON.FHM_1 - SON.FHM_4, SON.MRO_5]

MRO response to change of transmit power

If, at any time, transmit power of the cell is changed significantly, MRO restarts its operation. This is because significant change in transmit power typically results in significant change of handover boundaries for the cell. Thus, any learning or adjustments done by MRO prior to transmit power change, must not be used.

[test example: SON.MRO_14]

MRO response in case of too-late handovers

When MRO detects increase in handover failure rate or handover performance metric above the desired threshold due to occurrence of too-late handovers, it changes handover parameters to make them more handover friendly for all neighboring cells in order to reduce these too-late handovers.

If handover failure rate and handover performance metric is below the desired threshold, MRO does not change any handover parameters.

[test example: SON.MRO_2 - SON.MRO_3]

MRO response in case of too-early handovers

When MRO detects increase in handover failure rate or handover performance metric above the desired threshold due to occurrence of too-early handovers, it changes handover parameters to make them less handover friendly for all neighboring cells in order to reduce these too-late handovers.

If handover failure rate and handover performance metric is below the desired threshold, MRO does not change any handover parameters.

[test example: SON.MRO_6 - SON.MRO_7]

MRO response in case of handover to wrong cell

When MRO detects increase in handover failure rate or handover performance metric above the desired threshold due to occurrence of handovers to wrong cell, it first tries to solve the problem by making handover parameters for all neighboring cells less handover friendly. If that does not work or makes the problem worse, it tries to solve the problem by making handover parameters for all neighboring cells more handover friendly.

If handover failure rate and handover performance metric is below the desired threshold, MRO does not change any handover parameters.

NOTE: The above description assumes a simple implementation where MRO is not running per neighboring cell. Otherwise, CIO parameter may be used to solve the problem.

[test example: SON.MRO_8]

MRO response in case of ping-pong handovers

Ping-pong handovers are undesirable but are not strictly handover failures. Therefore, these are detected through handover performance metric only and not handover failure metric.

When MRO detects degradation in (identified by increase of) handover performance metric above the desired threshold due to occurrence of ping-pong handovers, it changes handover parameters for all neighboring cells to make them less handover friendly in order to reduce these ping-pong handovers.

If handover performance metric is below the desired threshold, MRO does not change any handover parameters.

[test example: SON.MRO_1]

A.3.5 cSON-OAM parameters

MRO configuration parameters

Table A-2 lists the MRO configuration parameters, which are also mentioned [S2].

Table A-2 MRO configuration parameters

Parameter name	Description	Reference
MROIntraFreqEnable	Enable/disable MRO for intra-frequency HO optimization	-
MROInterFreqEnable	Enable/disable MRO for inter-frequency HO optimization	-
HOFailureRate	Handover optimization target: Number of failure events related to handover divided by the total number of handover events. The target is met if the actual rate is smaller than the target value.	Sec 4.3.1 in 32.522 [S7]
Mobility Connected	Mobility parameter values for connected mode	

The MRO mobility parameters for connected mode are listed in Table A-3.

Table A-3 MRO mobility parameters for connected mode

Name	Description	Reference
CIO	Used for evaluating triggering conditions for measurement reporting in connected mode.	See TS 32.592 [S8] and TR-196 [S1] See Note below.
A1ThresholdRSRP	Corresponds to parameter a1-Threshold for UE measurement reporting, based on RSRP.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A1ThresholdRSRQ	Corresponds to parameter a1-Threshold for UE measurement reporting, based on RSRQ.	See TS 32.592 [S8] and TR-196 [S1] See Note below

Name	Description	Reference
A2ThresholdRSRP	Corresponds to parameter a2-Threshold for UE measurement reporting, based on RSRP.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A2ThresholdRSRQ	Corresponds to parameter a2-Threshold for UE measurement reporting, based on RSRQ.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A3-Offset	Corresponds to parameter a3-Offset specified for UE measurement reporting.	See TS 32.592 [S8] and TR-196 [S1]
A4ThresholdRSRP	Corresponds to parameter a4-Threshold for UE measurement reporting, based on RSRP.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A4ThresholdRSRQ	Corresponds to parameter a4-Threshold for UE measurement reporting, based on RSRQ.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A5Threshold1RSRP	Corresponds to parameter a5-Threshold1 for UE measurement reporting, based on RSRP.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A5Threshold1RSRQ	Corresponds to parameter a5-Threshold1 for UE measurement reporting, based on RSRQ.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A5Threshold2RSRP	Corresponds to parameter a5-Threshold2 for UE measurement reporting, based on RSRP.	See TS 32.592 [S8] and TR-196 [S1] See Note below
A5Threshold2RSRQ	Corresponds to parameter a5-Threshold2 for UE measurement reporting, based on RSRQ.	See TS 32.592 [S8] and TR-196 [S1] See Note below
Hysteresis	Corresponds to parameter hysteresis for UE measurement reporting. cSON may provide one or more values and/or range of values for the small cell dSON to choose from.	See TS 32.592 [S8] and TR-196 [S1]
TimeToTrigger	Corresponds to parameter timeToTrigger for UE measurement reporting. cSON may provide one or more values and/or range of values for the small cell dSON to choose from.	See TS 32.592 [S8] and TR-196 [S1]
FilterCoefficientRSRP	Corresponds to filterCoefficientRSRP parameter for UE measurement reporting. cSON may provide one or more values and/or range of values for the small cell dSON to choose from.	See TS 32.592 [S8] and TR-196 [S1]
FilterCoefficientRSRQ	Corresponds to filterCoefficientRSRQ parameter for UE measurement reporting. cSON may provide one or more values and/or range of values for the small cell dSON to choose from.	See TS 32.592 [S8] and TR-196 [S1]

NOTE: Current TR-196 [S1] specifies this parameter as a single value. It shall also be extended to provide one or more values (or a range of values) for the small cell dSON to choose from.

MRO Counters

The MRO counters are provided in Table A-4. These counters shall not be assumed to be available in case that MRO SON function is not implemented or is disabled.

Table A-4 MRO counters

Counter name	Description	Reference
ECGI[n]	Specifies target cells.	Defined in TS 36.423 [S10]
NumHOIntraFreqAttempt	Reporting period for number of attempted outgoing LTE intra-frequency handovers. Includes successful handovers plus all identified failures.	Sec 4.2.4.2.1 in 32.453 [S6]
NumHOInterFreqAttempt	Reporting period for number of attempted outgoing LTE inter-frequency handovers. Includes successful handovers plus all identified failures.	Sec 4.2.4.2.1 in 32.453 [S6]
NumHOIntraFreqSucc	Reporting period for number of successful outgoing LTE intra-frequency handovers.	Sec 4.2.4.2.2 in 32.453 [S6]
NumHOInterFreqSucc	Reporting period for number of successful outgoing LTE inter-frequency handovers.	Sec 4.2.4.2.2 in 32.453 [S6]
NumHOIntraFreqFailure	Reporting period for number of failed outbound intra-LTE intra-frequency handovers.	Sec 4.2.4.2.3 in 32.453 [S6]
NumHOInterFreqFailure	Reporting period for number of failed outbound LTE inter-frequency handovers.	Sec 4.2.4.2.3 in 32.453 [S6]
NumHOTooEarly	Reporting period for number of MRO too-early HO failure cases (ECGI) – MRO only.	Sec 4.3.5 in 32.522 [S7]
NumHOTooLate	Reporting period for number of MRO too-late HO failure cases (ECGI) – MRO only.	Sec 4.3.5 in 32.522 [S7]
NumHOWrongCell	Reporting period for number of MRO HO failures to a wrong cell, wrong cell (ECGI 1 instead of ECGI 2).	Sec 4.3.5 in 32.522 [S7]

A.4 Inter-Cell Interference Coordination (ICIC)

A.4.1 Scope

This chapter describes the Inter-cell Interference Coordination (ICIC) SON feature for interference management in downlink (DL) and how it interacts with other features and modules, and provides scenarios and call flows for using the feature. Recommendations on interactions of the ICIC feature with OAM/cSON are also provided for end-to-end interworking of the ICIC feature in multi-vendor SON deployments.

A.4.2 Feature executive summary

One cost effective solution to address the constantly increasing demand in capacity is the deployment of small cells. However, as the small cell density increases in such unplanned networks, inter-cell interference becomes a major challenge, especially for users located at cell edge. In fact, cell edge users see lower Signal-to-Interface Plus Noise Ratio (SINR), which results in lower throughput and poor user experience.

The increased amount of interference between neighboring SCs calls for effective techniques for radio resource management. The usage of radio-access network resources can be coordinated in time, space, and/or frequency to manage interference and different resource management techniques are possible. Firstly, one has to mention the in-cell RRM techniques, such as scheduling and link adaptation, which do not require inter-cell coordination. Other RRM techniques typically require some form of coordination between neighboring cells. In LTE, such coordination can be performed in a distributed way over the X2-interface. This allows the cells to exchange load and resource usage information among neighbors and thus enables ICIC.

In ICIC, frequency domain resource coordination is performed across cells in a dynamic (or adaptive) way to improve cell edge user throughput performance. The focus of this section is on downlink ICIC for interference management in DL. Distributed, self-configuring ICIC using Soft Fractional Frequency Reuse (SFFR) is recommended for DL IM where each small cell coordinates its resource partitioning as part of a self-configuration, based on the resource partitioning of the neighbors as learnt via the Relative Narrowband Transmit Power (RNTP) information element exchanged over X2.

In SFFR, the frequency resources of each SC are typically partitioned into two groups: cell center resources and cell edge (protected) resources. By serving the UEs which experience significant interference from neighboring SCs only in protected cell-edge resources and all other UEs in the remaining resources at de-boosted power, as well as ensuring that the cell-edge dedicated resources of neighboring SCs minimally interferer with one another, SFFR enables SINR gains for cell edge users. The SINR gain of cell edge users, in turn, enables improved cell-edge user performance and thus improved network-wide fairness.

The following functions and operations are supported in the SON ICIC feature:

- CER configuration: Initial as well as dynamic self-configuration
  [test example: SON.ICIC_1, SON.ICIC_8 - SON.ICIC_10]
- ICIC neighbor list management
  [test example: SON.ICIC_7, SON.ICIC_11, SON.ICIC_12]
- Dynamic user categorization and resource allocation
  [test example: SON.ICIC_2 - SON.ICIC_6]
- Improved cell-edge user performance,
  [test example: SON.ICIC_13]

A.4.3 Feature description

The key functions for ICIC operation are:

- **ICIC neighbor list management**: Identification of the relevant neighbors (strong interferers) to be considered in the CER self-configuration, maintenance of the list of such neighbors attributes (e.g., PCI, RSRP, RNTP) and exchanging coordination information with these neighbors.
- **Dynamic user categorization**: Identification of the users as cell-edge (CE) vs. cell-center (CC) users. CE users are users that experience strong interference from neighboring cells and should hence be served in dedicated cell-edge resources as given by the CER self-configuration procedure, in order to enable a SINR and throughput gain for such users. Such identification of CE vs. CC users is based on the effective SINR experienced by each UE (derived from the reported Channel Quality Indication (CQI) feedback).
- **CER self-configuration**: Computation of the number and position (which Physical Research Blocks (PRB)) of the dedicated CE resources (resource partitioning, aka color) to be used for serving the CE users, either out of a configured (finite) set of resource partitions (colors) as part of a self-(re)configuration at periodic updates or dynamically adapted , with the goal of avoiding the dominant interferers, based on the ICIC neighbor list and RNTP information received from neighbors in that list.

ICIC configuration parameters

Table A-5 lists the ICIC configuration parameters, which are also provided in [S2].

Table A-5 ICIC configuration parameters

Parameter name	Description	Reference
IMFreqEnable	Enable/disable Information Management (IM) algorithms using frequency domain partitioning (ICIC)	-
IMDLProtectedPRB	List of masks for protected PRB in DL the dSON can choose from. Each item is an RNTP vector (bit string) whose values indicate whether a promise to protect a DL PRB is given or not given (see TS 36.423 [S10], Section 9.2.19).	-
p-b	Equal to Eb/Ea. Is same for all UEs in the cell. Eb = EPRE (Energy Per Resource Element) of PDSCH REs type B, i.e., REs in OFDM symbols that include reference symbols. cSON may provide one or more values and/or range of values for the Small Cell dSON to choose from.	See [S8] and [S1]
p-a	Equal to Ea/Ers. Ea = EPRE (energy per resource element) of PDSCH REs (resource elements) type A, i.e., REs in OFDM symbols that do not include reference symbols. cSON may provide one or more values and/or range of values for the Small Cell dSON to choose from.	See [S8] and [S1]
p-a-High	Value of p-a for high-power PRBs in DL in Soft-FFR. The parameter is meaningful when the IMFreqHardFFR is set to *false*. cSON may provide one or more values and/or range of values for the Small Cell dSON to choose from.	-

ICIC Performance counters/statistics

The performance counters/statistics of interest to ICIC are provided in Table A-6 and are also mentioned in [S2].

Table A-6 RM performance counters

Name	Description	Reference
DL PRB Usage for traffic	Reporting period for the usage (in percentage) of Physical Resource Blocks (PRBs) on the downlink for Dedicated Traffic Channel (DTCH) traffic. The measurement is split into sub-counters per E-UTRAN Radio Bearer (E-RAB) Quality of Service (QoS) level (QCI).	Sec. 4.5.1 in [S4]
DL Total PRB Usage	Reporting period for the total usage (in percentage) of PRBs on the downlink for any purpose.	Sec. 4.5.3 in [S4]
DL PRB full utilization	Reporting period for the percentage of time during which all available PRBs for traffic on the downlink have been assigned	Sec. 4.5.9.1 in [S4]
DL PRB Usage for protected resources	Reporting period for DL PRB usage for protected resources. This measurement provides the usage (in percentage) of protected (PRBs on the downlink for DTCH traffic, according to DL mask – Information Management (IM) only.	