# 5G RAN6.1 New Feature and Application - VDF

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# Objectives

- Upon completion of this course, you will be able to:
  - Know the feature delta in RAN6.1
  - Understand principles and parameters for new features in RAN6.1



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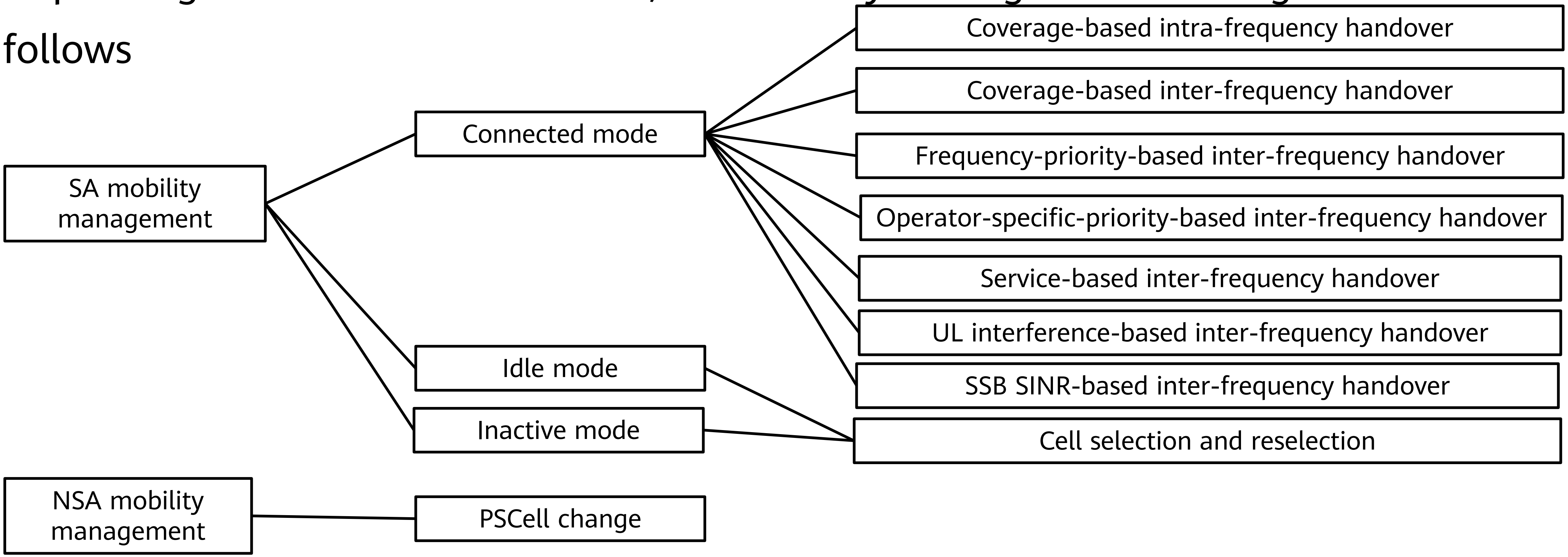
# Mobility Management Solution in RAN6.1

- Depending on network architecture, NR mobility management is categorized as follows

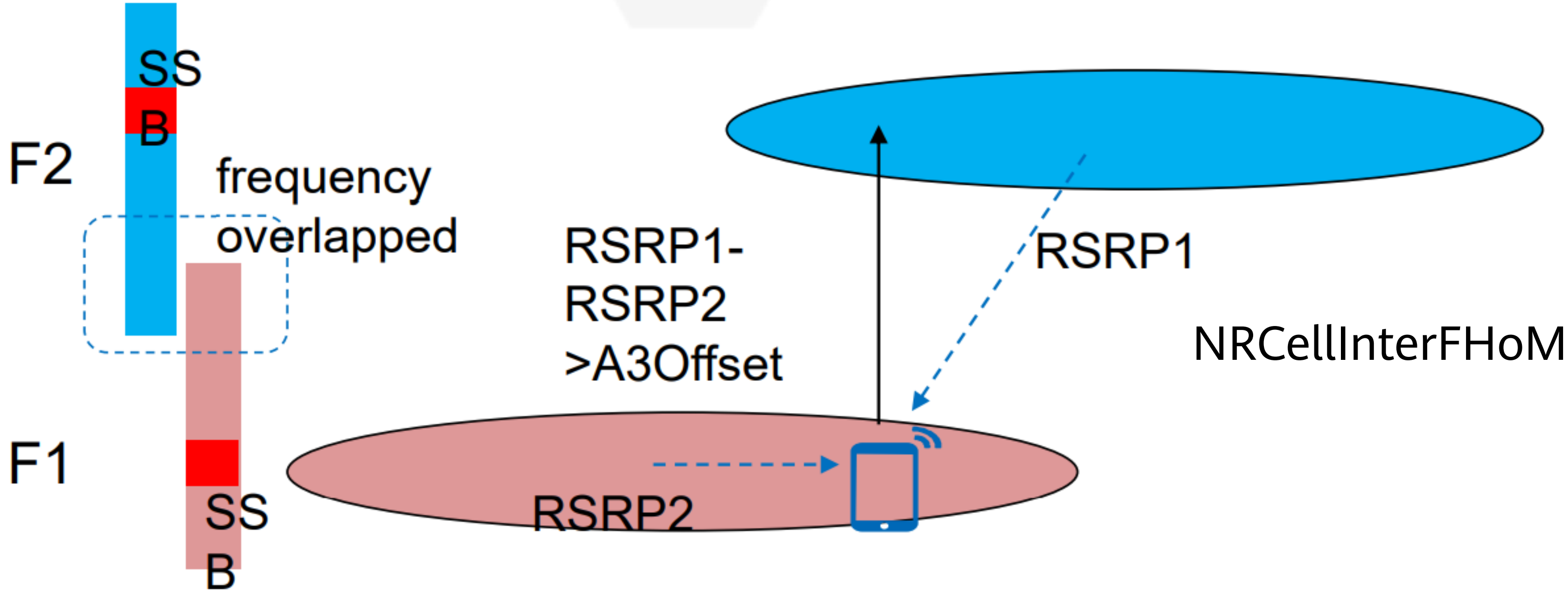



NSA and SA use the same algorithms and parameters for connected mode mobility control

# Key Changes in RAN6.1 Mobility

- This issue includes the following changes:
  - For UEs in the RRC_CONNECTED state
    - A3 event can be used for coverage based inter-frequency handover
    - Added a neighboring cell filtering rule to filter out the neighboring cells whose frequency bands do not match UE frequency band capabilities
    - Supported subscription to uplink interference information about inter-frequency neighboring cells
    - Supported inter-frequency handover collaboration
  - For UEs in the RRC_IDLE state
    - Supported speed-based cell reselection

# Event A3 Supported for Inter-frequency Handover

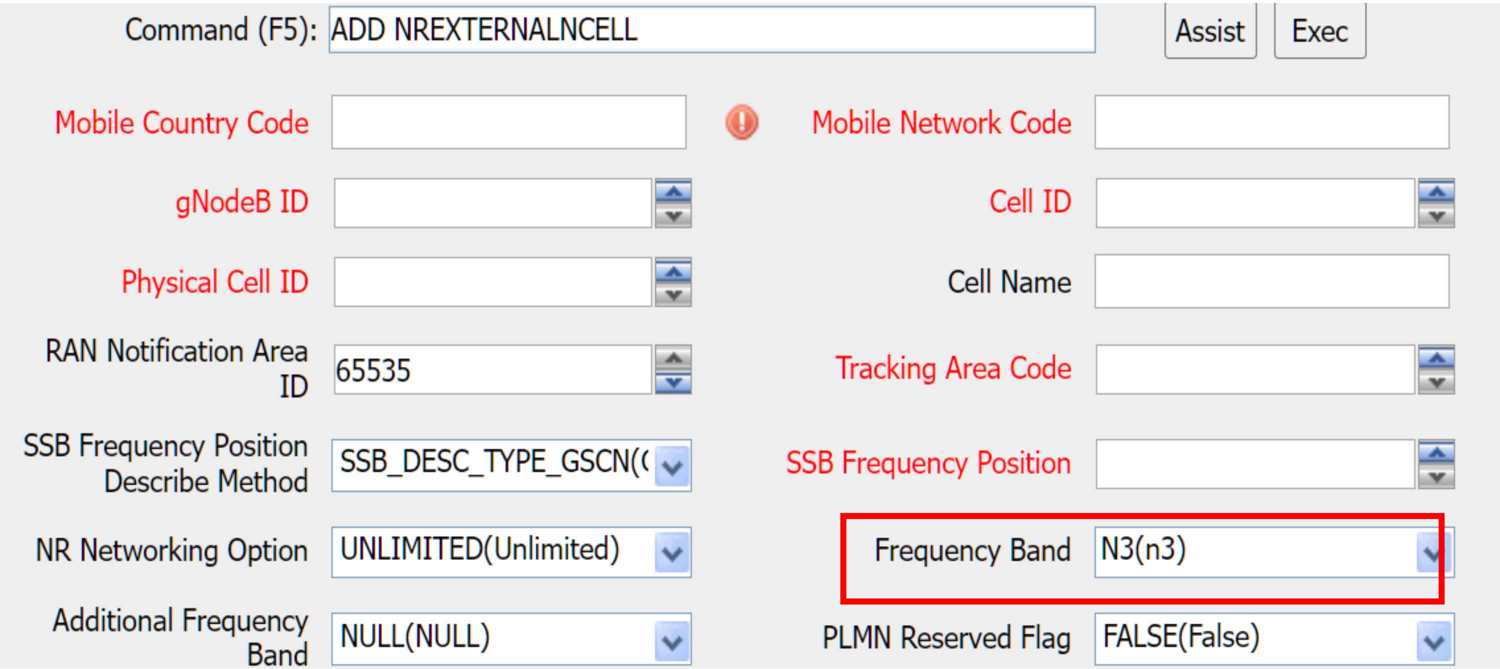



NRCellInterFHoMeaGrp. InterFreqHoA3Offset

- By the way of relative threshold triggered handover can effectively avoid the risk of frequency interference
- The event type can be configured based on different inter frequency

# Neighbor Cell Filtering Rules

- During inter-frequency handover decision phase
  - The gNodeB filters out the neighboring cells whose frequency bands do not match UE frequency band capabilities. The neighbor frequency indicator can be configured via external cell



# Subscription to Uplink Interference for Inter-F HO

- Purpose: during the HO target decision, the source cell can obtain the neighbor cell interference for the further decision
- When subscription to uplink interference information about inter-frequency neighboring cells is enabled:
  - If the serving cell has obtained uplink interference information about neighboring cells, the gNodeB will filter out neighboring cells with high uplink interference from candidate neighboring cells
  - This function can be applied for unnecessary inter-frequency handover.



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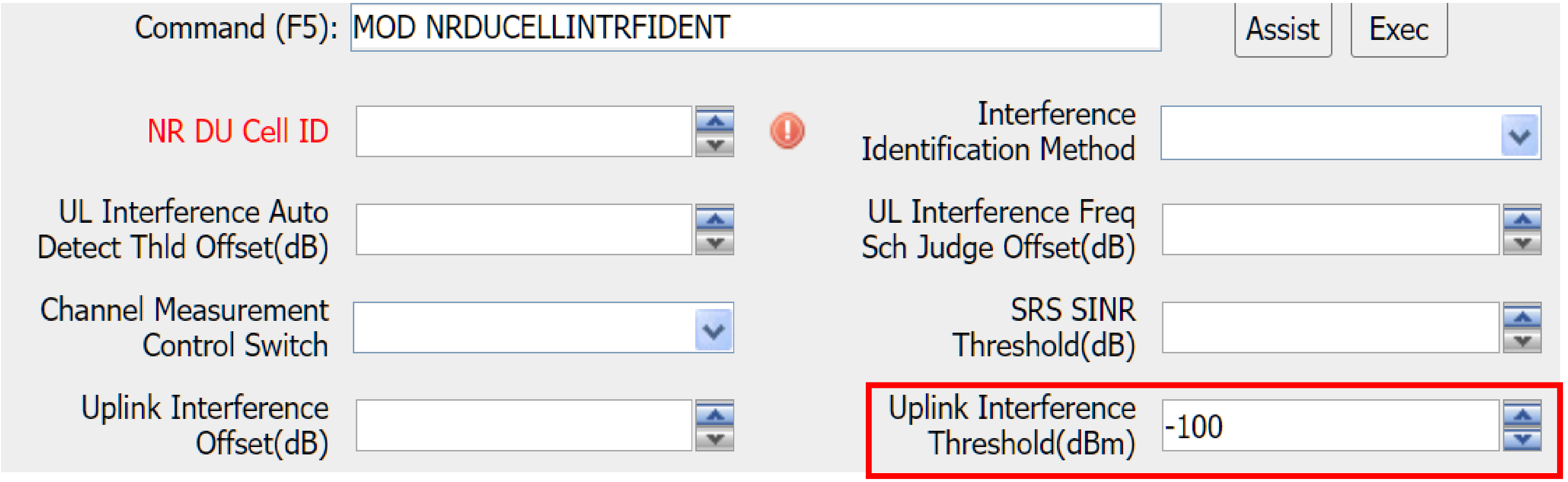
# Subscription to Uplink Interference for Inter-F HO (*Cont.*)

<table>
<tr><th>Handover Scenario</th><th>Applied Rule</th></tr>
<tr><td>Frequency-priority-based inter-frequency handover</td><td rowspan="5">Neighboring cells with high uplink interference are filtered out from candidate neighboring cells.<br>• A neighboring cell is regarded as a low-uplink-interference cell when its uplink interference strength is less than or equal to NRDUCellIntrfIdent.UlIntrfThld.<br>• A neighboring cell is regarded as a high-uplink-interference cell when its uplink interference strength is greater than NRDUCellIntrfIdent.UlIntrfThld.</td></tr>
<tr><td>Operator-specific-priority-based inter-frequency handover</td></tr>
<tr><td>Service-based inter-frequency handover</td></tr>
<tr><td>Uplink-interference-based inter-frequency handover</td></tr>
<tr><td>SSB SINR-based inter-frequency handover</td></tr>
</table>



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# Inter-frequency Handover Collaboration

- When inter-frequency handover collaboration is enabled, the serving cell filters out neighboring cells that have entered the MLB state or does not initiate handovers for UEs having voice bearers
  - If the following unnecessary handovers are enabled for the serving cell and inter-frequency MLB by transferring UEs in connected mode is enabled for the target cell, inter-frequency handover collaboration can be used to avoid ping-pong handover. The applied rules are as follows:

# Inter-frequency Handover Collaboration(*Cont.*)

<table>
<tr><th>Handover Scenario</th><th>Applied Rule</th></tr>
<tr><td>Frequency-priority-based inter-frequency handover</td><td>• When selecting a target cell for a handover, the serving cell filters out neighboring cells that have entered the MLB state to avoid ping-pong handover.<br>• The serving cell checks whether the UE has a voice bearer.<br>  • If so, handover is not initiated, thereby avoiding ping-pong handover.<br>  • If not, the handover initiation procedure proceeds.</td></tr>
<tr><td>Operator-specific-priority-based inter-frequency handover</td><td rowspan="4">When selecting a target cell for a handover, the serving cell filters out neighboring cells that have entered the MLB state to avoid ping-pong handover.</td></tr>
<tr><td>Service-based inter-frequency handover</td></tr>
<tr><td>Uplink-interference-based inter-frequency handover</td></tr>
<tr><td>SSB SINR-based inter-frequency handover</td></tr>
</table>

# Speed-based Cell Reselection

- When speed-based cell reselection is enabled, a UE can evaluate its speed based on the system information broadcast by the gNodeB and then use appropriate cell reselection parameters adaptive to its speed for cell reselection
- UE evaluates its speed based on the SI broadcast by the gNodeB. The criteria for evaluation are as follows:
  - Normal-mobility UE: The number of reselected cells is less than or equal to **n-CellChangeMedium** within a **t-Evaluation** duration and the number of reselected cells is less than or equal to **n-CellChangeMedium** within the subsequent **t-HystNormal** duration (fixed at 30s)
  - Medium-mobility UE: The number of reselected cells is greater than **n-CellChangeMedium** but less than or equal to **n-CellChangeHigh** within a **t-Evaluation** duration
  - High-mobility UE: The number of reselected cells is greater than **n-CellChangeHigh** within a **t-Evaluation** duration



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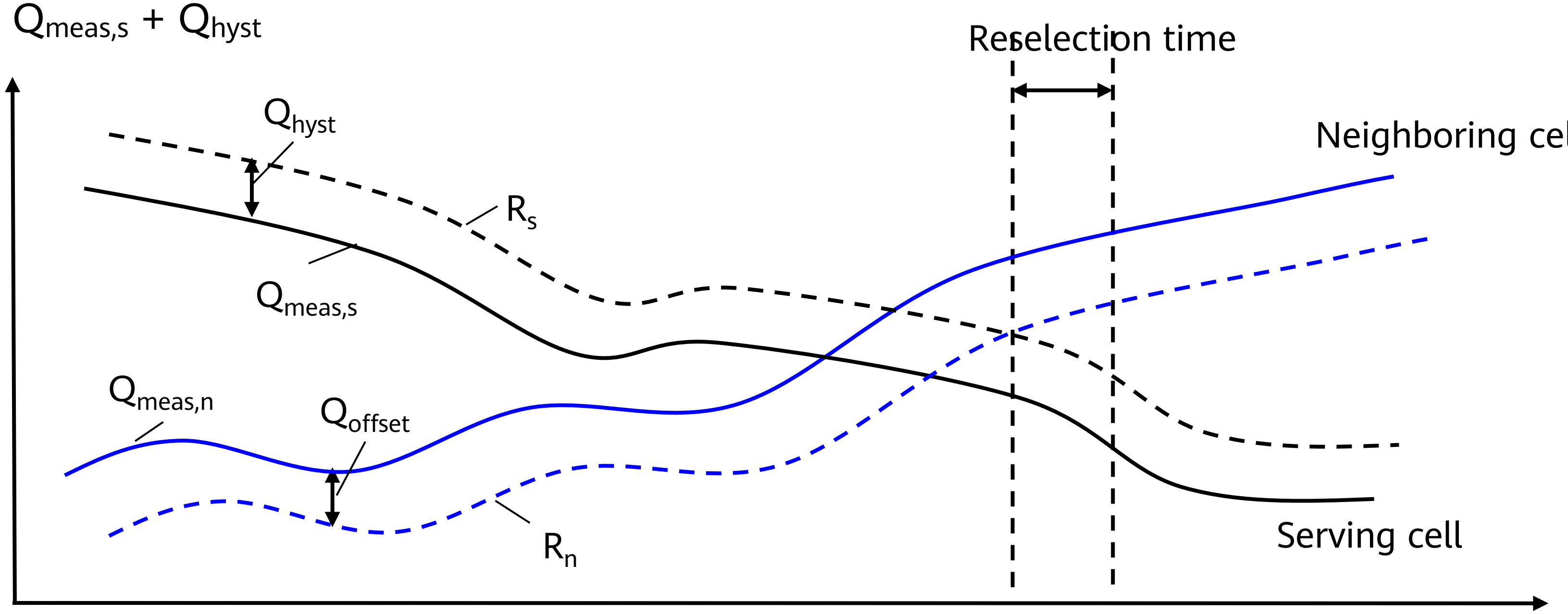
# Cell Reselection Rules Review

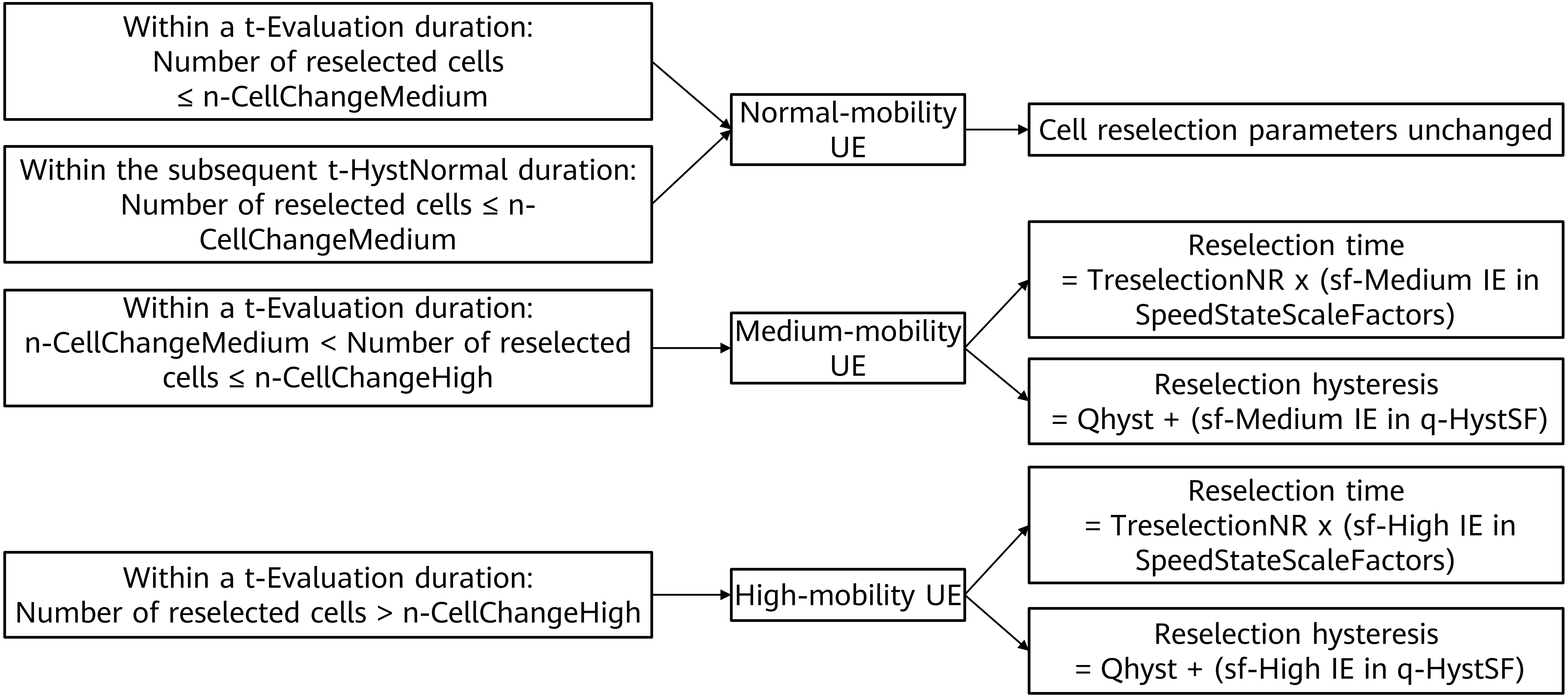
- R criteria (Intra frequency or equal priority inter frequency cell reslection)
  - The UE has camped on the serving cell for more than 1s
  - The best cell meets the cell reselection criteria (criterion R: $R_n > R_s$) consecutively for reselection time
    - $R_n = Q_{meas,n} - Q_{offset}$
    - $R_s = Q_{meas,s} + Q_{hyst}$



# Cell Reselection Rules Review (*Cont.*)

- S criteria
  - Low priority to high priority cell resection
    - Neighbor Cell $S_{rxlev}$ > ThreshXHigh within reselection time
  - High priority to low priority: both of following conditions are met within reselection time
    - Serving cell $S_{rxlev}$ < ThreshServinglow
    - Neighbor cell $S_{rxlev}$ > ThreshXlow

# Speed Based Cell Reselection Solution



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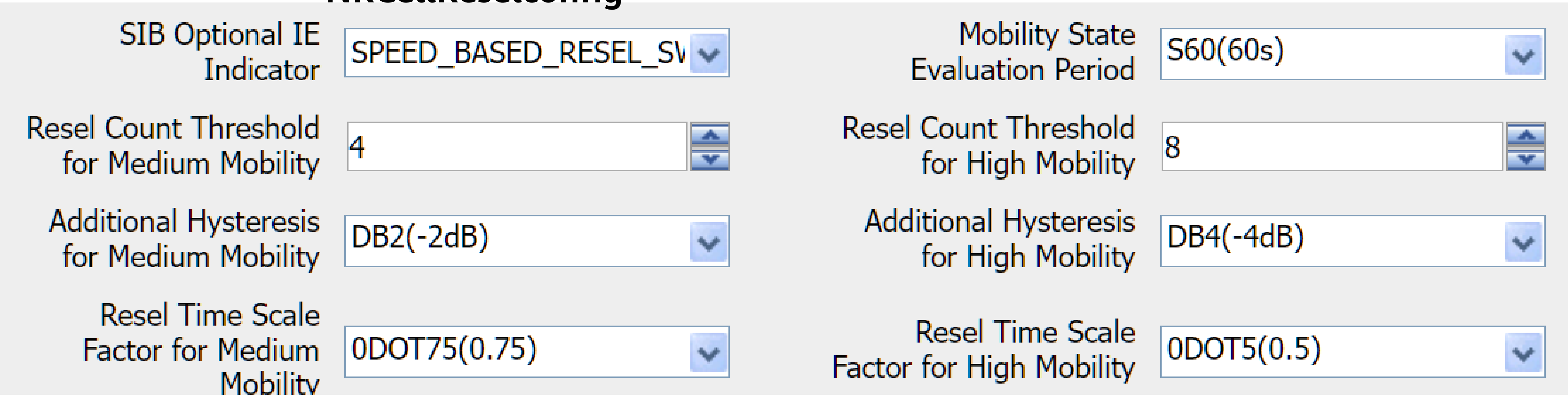
# Speed Based Cell Reselection Solution(*Cont.*)

- The following are the key parameters for speed based cell reselection

**NRCellReselconfig**




Flag to enable feature is the **NRCellReselConfig**.SibOptionalIeInd=**SPEED_BASED_RESEL_SW**





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# Mobility Management Network Analysis

- Benefits
  - A new neighboring cell filtering rule to filter out the neighboring cells whose uplink and downlink bandwidths do not match UE bandwidth capabilities: It ensures that coverage is continuous and service experience is consistent for moving UEs.
  - Support for blind redirection optimization by coverage-based inter-frequency handover: It reduces the service drop rate.
  - Subscription to uplink interference information about inter-frequency neighboring cells: It enables the serving cell to obtain uplink interference information about inter-frequency neighboring cells. This prevents UEs from being handed over to inter-frequency neighboring cells with high uplink interference in the case of unnecessary handover, thereby preventing ping-pong handover.
  - Inter-frequency handover collaboration: It prevents ping-pong handover and improves user experience.
  - Speed-based cell reselection: It improves the performance of cell reselection for UEs that support speed-based cell reselection and move at medium or high speeds, thereby reducing the number of service drops.



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# Mobility Management Network Analysis (Cont.)

- Impacts

  None





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# Mobility Management Feature Deployment

- A new neighboring cell filtering rule to filter out the neighboring cells whose uplink and downlink bandwidths do not match UE bandwidth capabilities, support for blind redirection optimization by coverage-based inter-frequency handover, subscription to uplink interference information about inter-frequency neighboring cells, inter-frequency handover collaboration, and speed-based cell reselection
  - Dependency

# Mobility Management Feature Deployment

- Licenses
  - None

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>All NR-capable main control boards and baseband processing units<br>• RF Modules<br>NR-capable RF modules |
| **Software Requirements** | • Prerequisite Functions<br>None<br>• Mutually Exclusive Functions<br>None |
| **Network Requirements** | None |
| **NE Requirements** | None |



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# Mobility Management Feature Deployment (Cont.)

- Activation Command Examples

  //Enabling blind redirection optimization (*This command is a high-risk command.)*

  MOD NRCELLALGOSWITCH: NrCellId=0, ProcessSwitch=A2_BLIND_REDIRECT_CTRL_SW-1;

  //Enabling subscription to uplink interference information about inter-frequency neighboring cells (*This command is a high-risk command.*)

  MOD NRCELLALGOSWITCH: NrCellId=0, NCellInfoCtrlSwitch=INTER_FREQ_UL_INTRF_SW-1;

  //Enabling inter-frequency handover collaboration (*This command is a high-risk command.*)

  MOD NRCELLALGOSWITCH: NrCellId=0, InterFreqHoSwitch=INTER_FREQ_HO_COLLABORATION_SW-1;

# Mobility Management Feature Deployment (Cont.)

- Activation Command Examples

  //Configuration for enabling speed-based cell reselection

  //Setting the UE mobility state evaluation period, threshold expressed as a number of cell reselections for evaluating whether UEs enter the medium-mobility state, threshold expressed as a number of cell reselections for evaluating whether UEs enter the high-mobility state, scaling factor for the cell reselection time of medium-mobility UEs, scaling factor for the cell reselection time of high-mobility UEs, additional hysteresis for cell reselection by medium-mobility UEs, and additional hysteresis for cell reselection by high-mobility UEs

  MOD NRCELLRESELCONFIG: NrCellId=0, MobStateEvalPeriod=S60, ReselThldForMediumMob=4, ReselThldForHighMob=8, ReselTimeSfForMediumMob=1DOT0, ReselTimeSfForHighMob=0DOT75, AddlHystForMediumMob=DB0, AddlHystForHighMob=DB0;

# Mobility Management Feature Deployment (Cont.)

//Enabling speed-based cell reselection

MOD NRCELLRESELCONFIG: NrCellId=0, SibOptionalIeInd=SPEED_BASED_RESEL_SW-1;

//Enabling speed-based cell reselection to inter-frequency or inter-RAT neighboring cells

MOD NRCELLRESELCONFIG: NrCellId=0, SibOptionalIeInd=INTER_FREQ_RAT_SPEED_RESEL_SW-1;

# Mobility Management Feature Verification

- Activation Verification
  - Speed-based cell reselection
    - After the related configurations are complete on the gNodeB, check SIB2, SIB4, or SIB5 in the current serving cell.

1. Start Uu signaling tracing: Log in to the MAE-Access and choose **Monitor** > **Signaling Trace** > **Signaling Trace Management**. On the displayed page, choose **Trace Type** > **NR** > **Application Layer** > **Uu Interface Trace**.
2. After speed-based cell reselection is enabled, this function has taken effect if the gNodeB-delivered SIB2 contains the IEs t-Evaluation, n-CellChangeMedium, n-CellChangeHigh, sf-Medium in q-HystSF, sf-High in q-HystSF, sf-Medium in SpeedStateScaleFactors, and sf-High in SpeedStateScaleFactors, with their values the same as the settings of configured parameters.

# Mobility Management Feature Verification

3. In inter-frequency or inter-RAT networking, when the **INTER_FREQ_RAT_SPEED_RESEL_SW** option of the **NRCellReselConfig**.SibOptionalIeInd parameter is selected, speed-based cell reselection to inter-frequency or inter-RAT neighboring cells has taken effect if the gNodeB-delivered SIB4 or SIB5 contains the IEs sf-Medium and sf-High in SpeedStateScaleFactors, with their values the same as the settings of configured parameters.

- Other Changes
  - None

# Section Summary

- For UEs in the RRC_CONNECTED state
  - A new neighboring cell filtering rule to filter out the neighboring cells whose frequency band doesn’t match UE capability
  - Support for subscription to uplink interference information about inter-frequency neighboring cells
  - Support for inter-frequency handover collaboration
- For UEs in the RRC_IDLE state
  - Support for speed-based cell reselection

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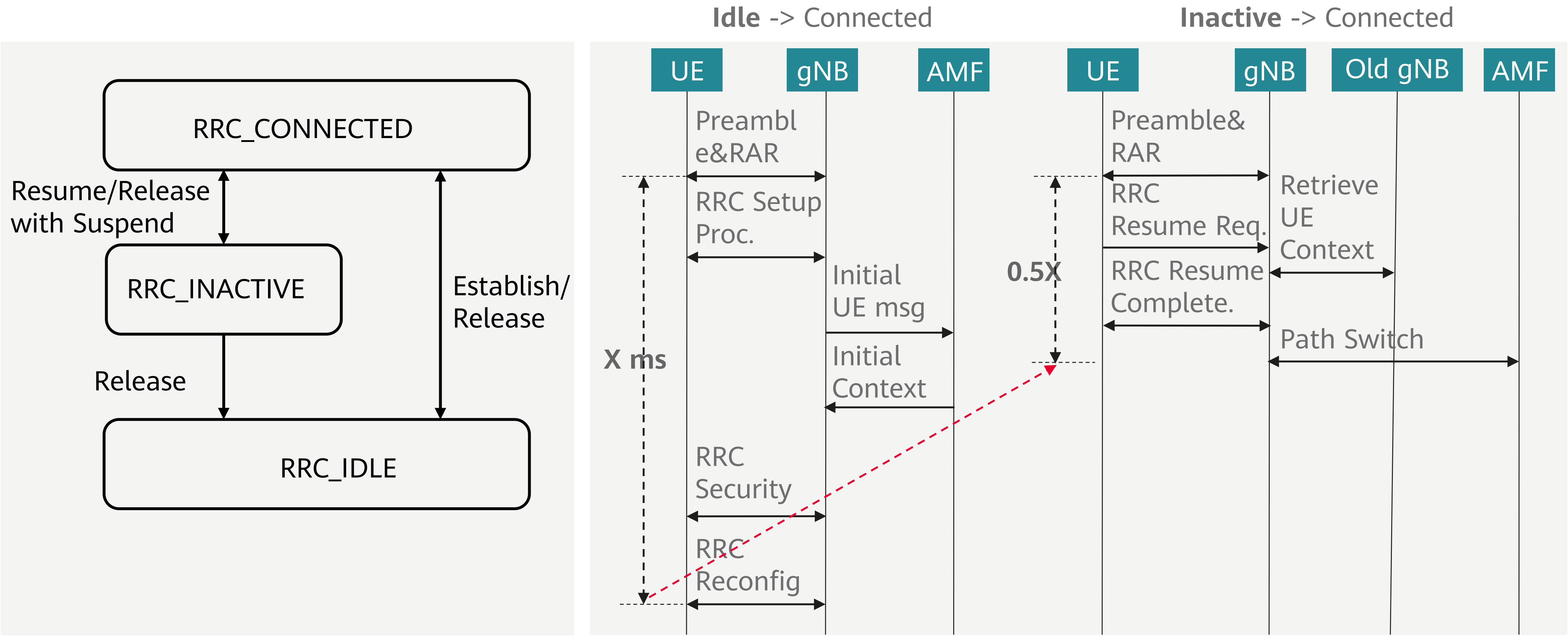
# SA Mobility Management in Inactive Mode

- The RRC_INACTIVE state is introduced to NR. The UE in the RRC_INACTIVE state can maintain the similar level of power consumption as it were in the RRC_IDLE state while resuming data transmission within a short delay.



# State Transition from RRC_CONNECTED to RRC_INACTIVE

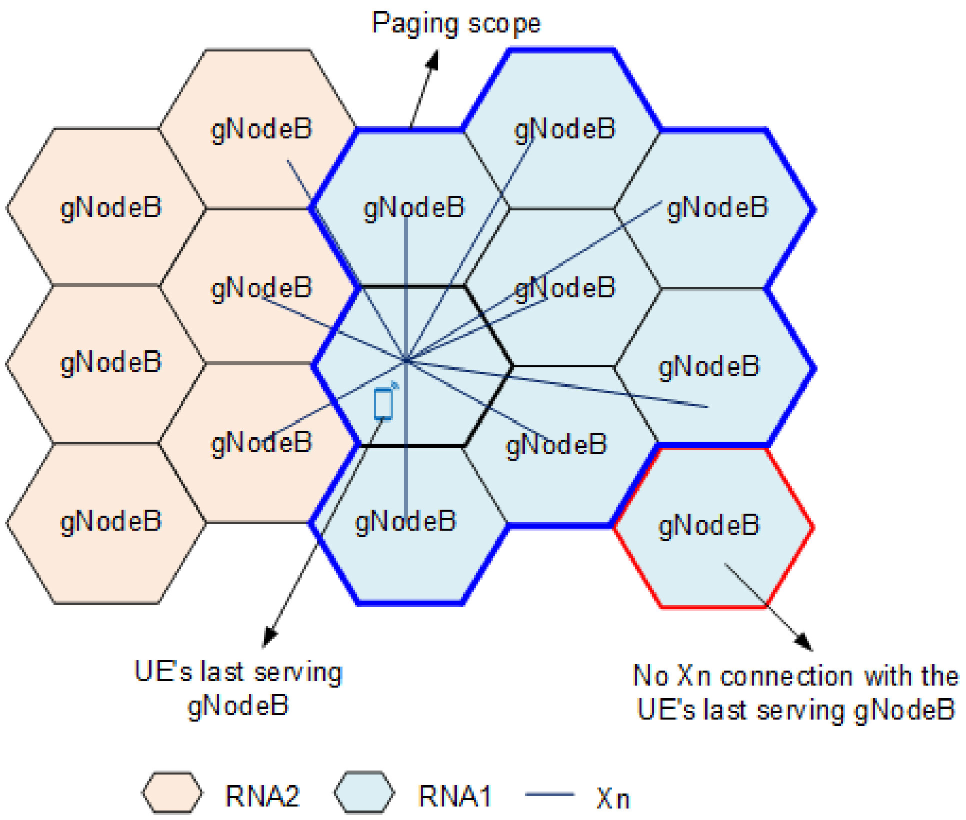
- An RRC_CONNECTED UE enters the RRC_INACTIVE state when all of the following conditions are met:
  - The switch for the RRC_INACTIVE state is turned on, and the UE supports this state.
  - The no-data-transmission duration of the UE exceeds the value of the **NRDUCellQciBearer.**UeInactivityTimer parameter.
  - The RNA ID of the serving cell has been planned. That is, the **NRDUCell**.RanNotificationAreaId parameter is set to a valid value (not 65535).

# States for RRC_INACTIVE terminal

- An RRC_INACTIVE UE performs cell search, PLMN selection, cell selection, cell reselection, RNA update, and state transition during its movement.
  - Cell search, PLMN selection, cell selection, and cell reselection: Their mechanisms are the same as those in idle mode.
  - RNA update: This procedure helps acquire the correct RNA of the UE on the move.
  - State transition: The UE changes its state to RRC_CONNECTED or RRC_IDLE in response to the change in service status.

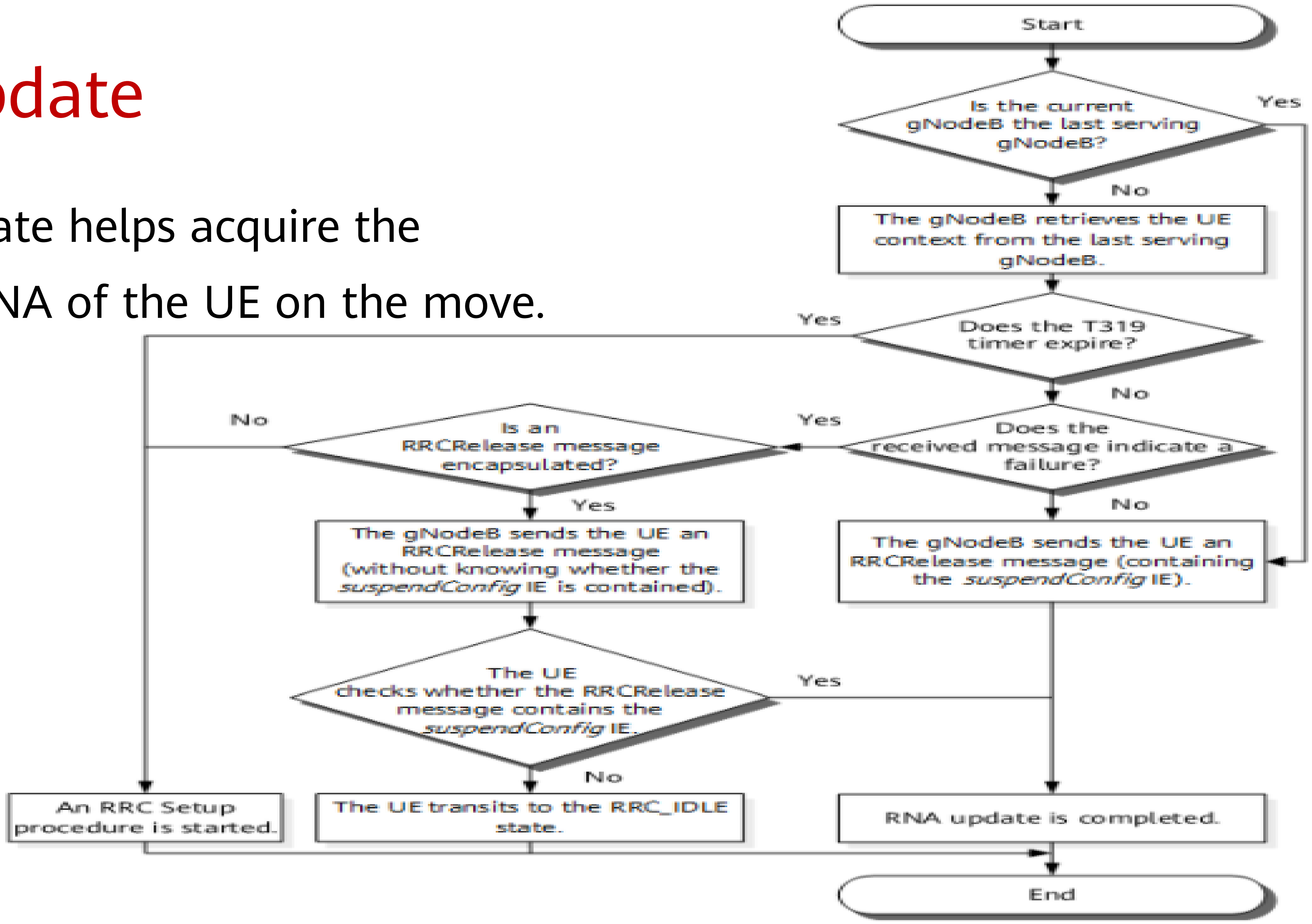
# RNA Introduction

- As illustrated in the following figure, a UE belongs to RNA1. RNA refers to RAN-based Notification Area. In a RAN paging, paging messages are sent to all RNA1 cells that are served by gNodeBs having Xn connections with the last serving gNodeB and for which the **NREXTERNALNCELL**.RanNotificationAreaId parameter is set to the ID of RNA1.



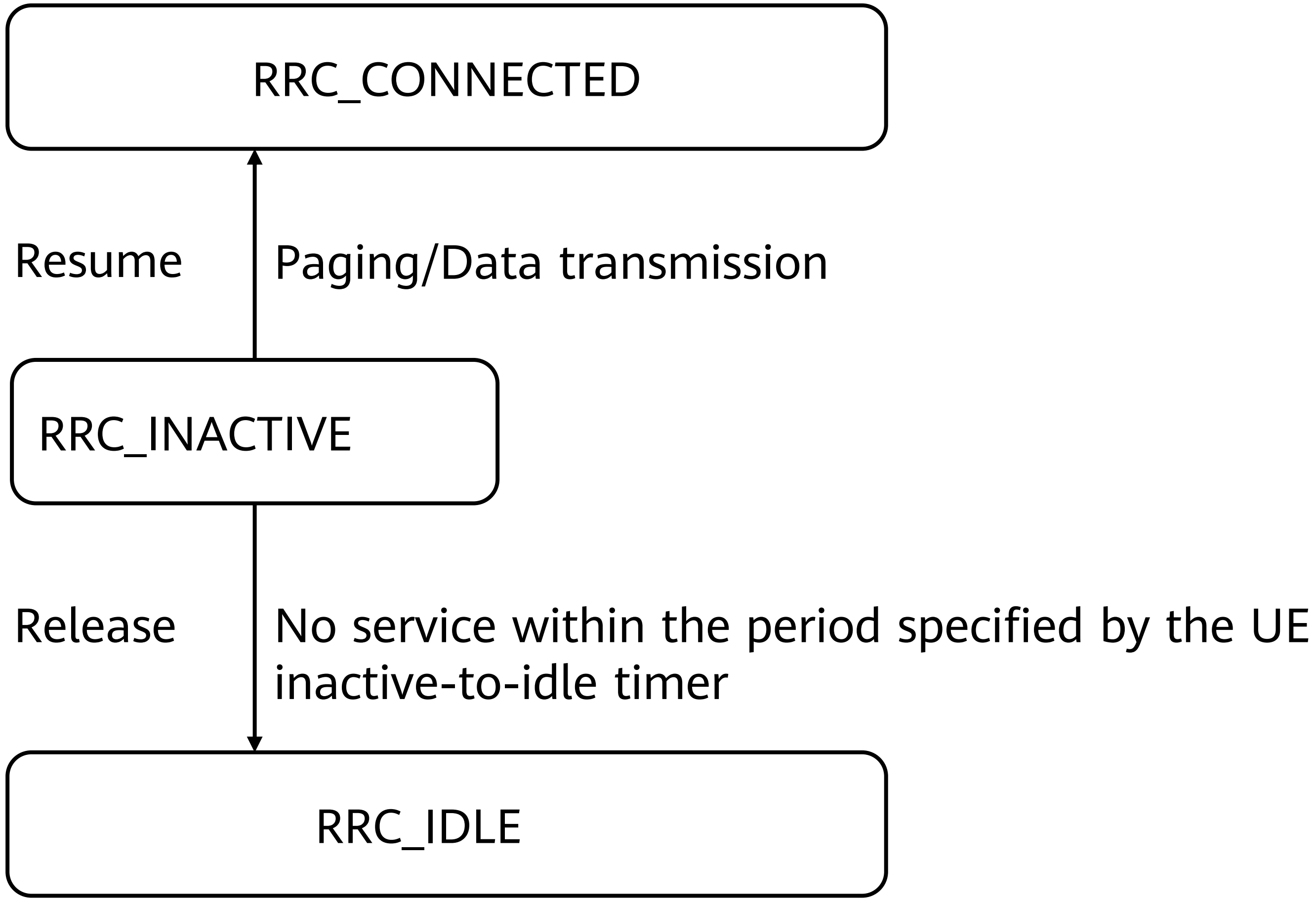
# RNA Update

- RNA update helps acquire the correct RNA of the UE on the move.



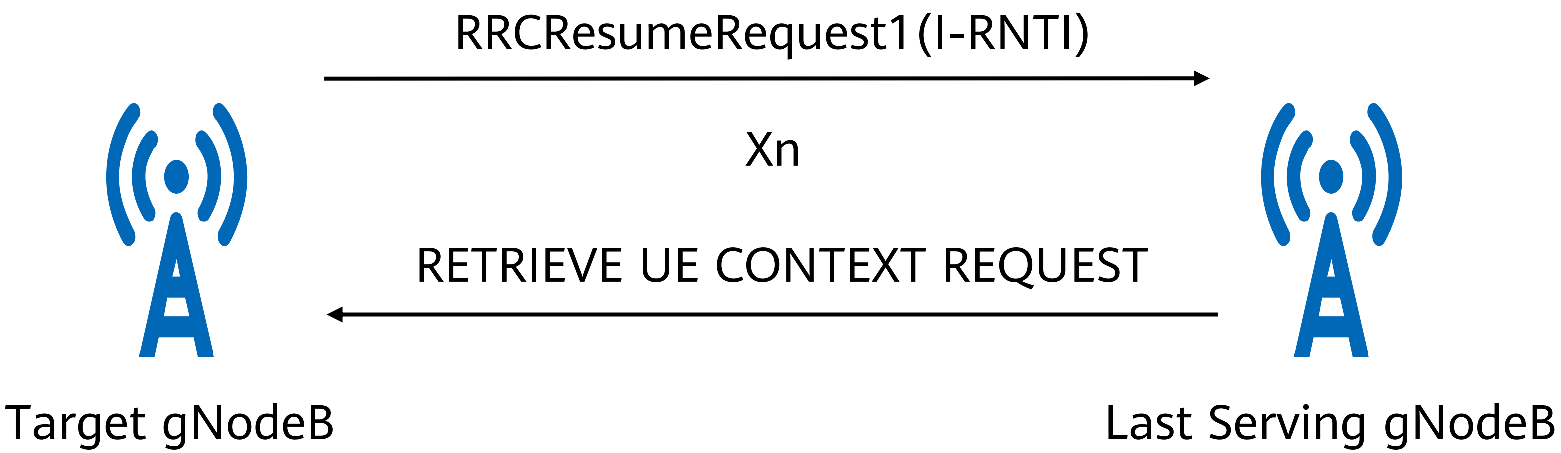
# State Transition from RRC_INACTIVE

- An RRC_INACTIVE UE can transit to the RRC_CONNECTED or RRC_IDLE state.



# UE Context Retrieval

- During an inter-gNodeB RNA update or transition from RRC_INACTIVE to RRC_CONNECTED, the target gNodeB needs to retrieve UE context information from the last serving gNodeB over the Xn interface.



# Operator-specific RAN Area Code and Inactive-to-Idle Timer Length Configuration

- In multi-operator sharing scenarios, RAN area codes can be configured separately for operators. When RAN paging is triggered, each operator sends its own RAN Notification Area ID, and the UE receives only the RAN paging of the subscribed operator.
- The RAN area code can be configured separately for operators through the **NRDUCellOp.RanNotificationAreaId** parameter.
- Impact on the Network
  - RAN area codes can be configured separately for operators to meet their requirements for flexible networking policies.
  - Inactive-to-idle timer length configuration: The length of the timer can be tailored to meet customers' specific requirements.

# Parameters for SA Mobility Management in Inactive Mode

- It is recommended that the following parameters be configured.

| Parameter Name | Parameter ID | Value | Mandatory/ Recommended |
|---|---|---|---|
| RAN Notification Area ID | **NRDUCELL**.RanNotificationAreaId | Set this parameter based on the network plan. | Mandatory |
| RAN Notification Area ID | **NREXTERNALNCELL**.RanNotificationAreaId | Set this parameter based on the network plan. | Recommended |
| INACTIVE Strategy Switch | **NRCellAlgoSwitch**.InactiveStrategySwitch | Select the RRC_INACTIVE_SWITCH option. | Recommended |
| UE Inactivity Timer | **NRDUCellQciBearer**.UeInactivityTimer | Set this parameter based on the network plan. | Recommended |
| Timer T319 | **NRDUCellUeTimerConst**.T319 | Set this parameter based on the network plan. | Recommended |
| UE Inactive To Idle Timer | **gNBConnStateTimer**.UeInactiveToIdleTimer | 1500 | Recommended |



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# Network Monitoring

- This function can be monitored using the following KPIs:
  - RRC Setup Success Rate (CU, Inactive)
  - QoS Flow Setup Success Rate (CU, Inactive)
  - Service Call Drop Rate (CU, Inactive)

# Q&A

- 1. How long must a UE not perform any services before it can transit from RRC_CONNECTED to RRC_INACTIVE?
  - A. Depends on the parameter configuration
  - B. 10s
  - C. 20s
  - D. 30s

# Q&A

- 2. How long must a UE not perform any services and keep its serving gNodeB unchanged before it can transit from RRC_INACTIVE to RRC_IDLE?
  - A. 1000s
  - B. 1200s
  - C. 1500s
  - D. 1600s

# Section Summary

- Conditions for entering the RRC_INACTIVE state
  - The switch for the RRC_INACTIVE state is turned on, and the UE supports this state.
  - The UE transits from RRC_CONNECTED to RRC_INACTIVE when its no data transmission duration exceeds a specified period.
- Basic concepts of RNA
  - RAN paging is triggered within an RNA.
  - There are Xn interfaces between the gNodeBs in the same RNA.
- RNA update
  - A UE periodically (at a fixed interval of 1200s) sends an RRCResumeRequest1 message with the cause value "RNA Update" to the gNodeB.

# Section Summary

  - After cell reselection, RNA update is triggered if the UE finds that the RNA ID of the new cell is different from the latest obtained RNA ID.
- Conditions for transition from the RRC_INACTIVE state
  - When a UE receives a RAN-based paging message or has data to send to the network, the UE transits from RRC_INACTIVE to RRC_CONNECTED.
  - If a UE does not perform any services and its serving gNodeB does not change within 1500s, the UE transits from RRC_INACTIVE to RRC_IDLE.
- UE context retrieval
  - The target gNodeB needs to retrieve UE context information from the last serving gNodeB over the Xn interface.
- Operator-specific RAN area code configuration



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# Extended Reading

For more on SA mobility management in inactive mode, scan the QR code to visit the Wireless Tech Series.

Alternatively, go to support.huawei.com > Product Support > Wireless Network > Bookshelf > Tech Series.

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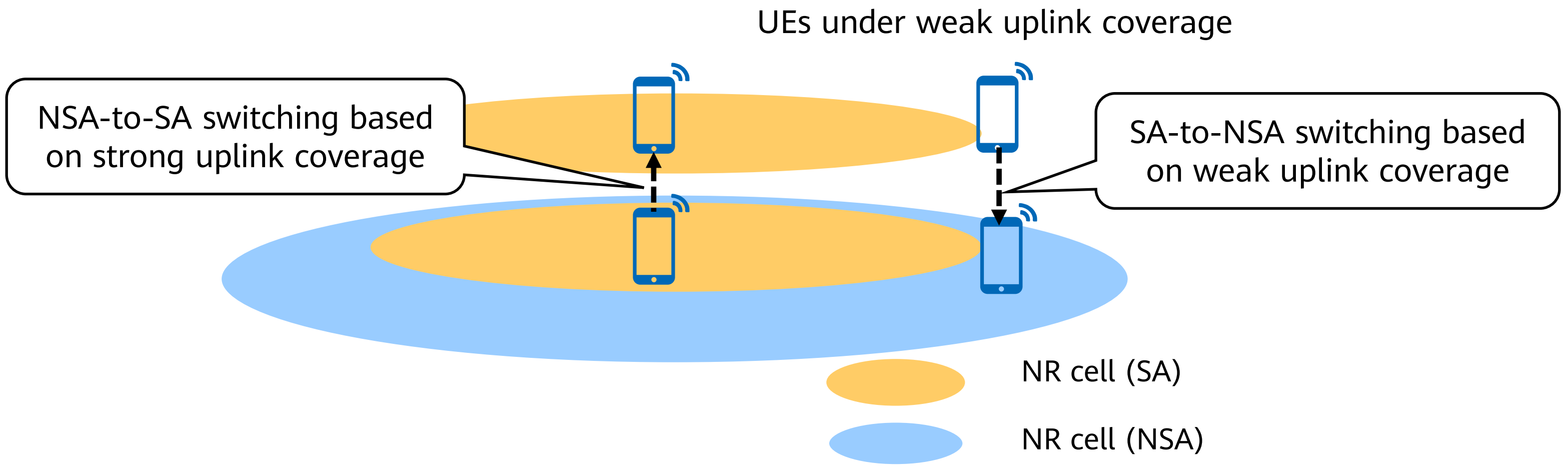
# NSA/SA Selection Based on User Experience Overview

- The NSA&SA capable UE may be experienced NR-EUTRAN interworking
- Besides the coverage based interworking, user experience based inter-working functions are also introduced
  - NSA/SA selection based on downlink traffic( Introduced in SRAN17.1)
    - Trigger the inter-working from NR to EUTRAN(SA to NSA) for high traffic UE
  - NSA/SA selection based on uplink coverage (New feature in SRAN18.1)
    - Support bi-direction inter-working based on uplink coverage

# Principles of NSA/SA Selection Based on User Experience

The following functions are added to NSA/SA selection based on user experience:

- SA-to-NSA switching based on weak uplink coverage
- NSA-to-SA switching based on strong uplink coverage




This function selects a networking mode that can provide a better service experience for UEs based on the uplink coverage of the UEs. It works only in scenarios with NR TDD cells and LTE FDD cells.

# Principles of NSA/SA Selection Based on User Experience (Cont.)

- SA-to-NSA switching based on weak uplink coverage involves the following two steps:
  1. The gNodeB identifies UEs under weak uplink coverage.
  2. The gNodeB performs SA-to-NSA switching for the UEs under weak uplink coverage.
- NSA-to-SA switching based on strong uplink coverage involves the following two steps:
  1. The gNodeB identifies UEs under strong uplink coverage.
  2. The gNodeB performs NSA-to-SA switching for the UEs under strong uplink coverage.



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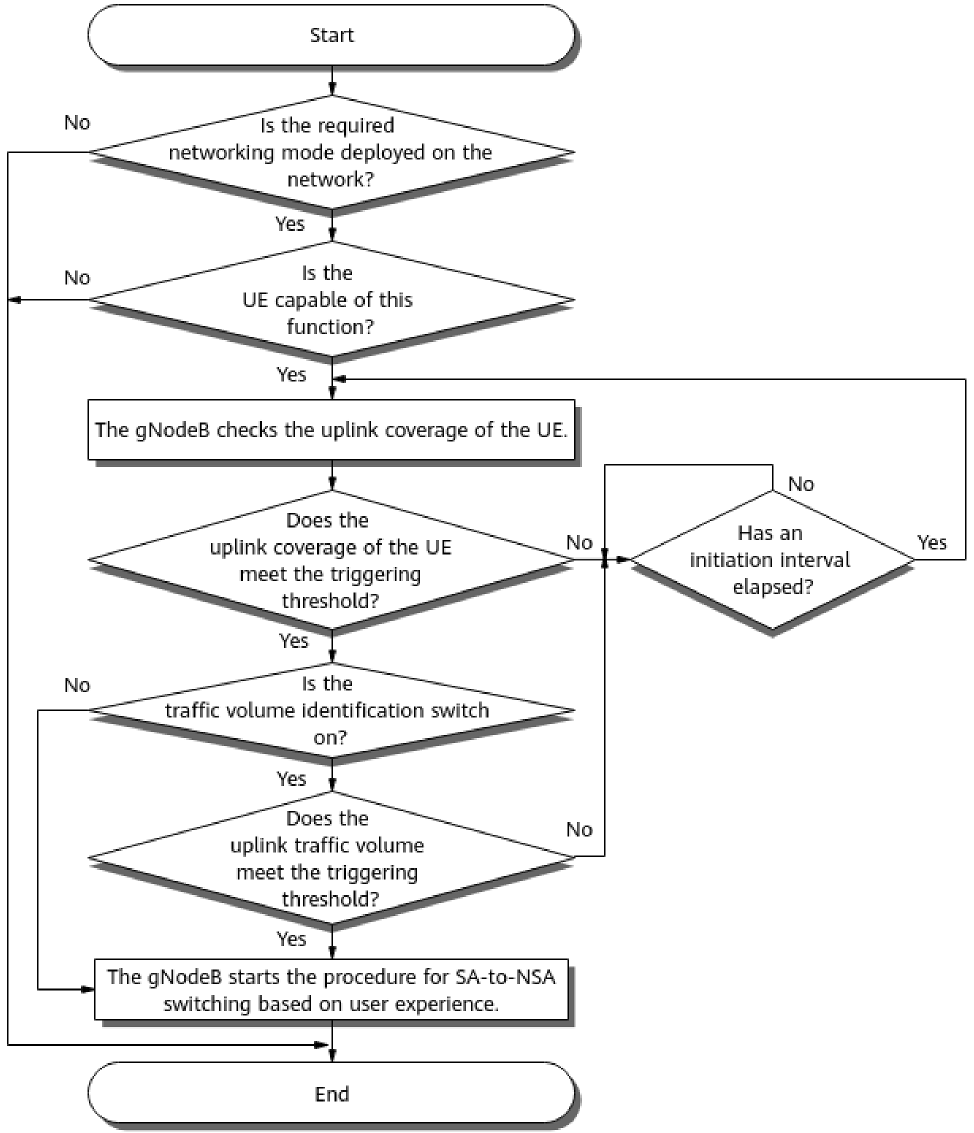
# SA-to-NSA Switching Based on Weak Uplink Coverage

- The gNodeB initiates SA-to-NSA switching based on user experience for identified UEs under weak uplink coverage:



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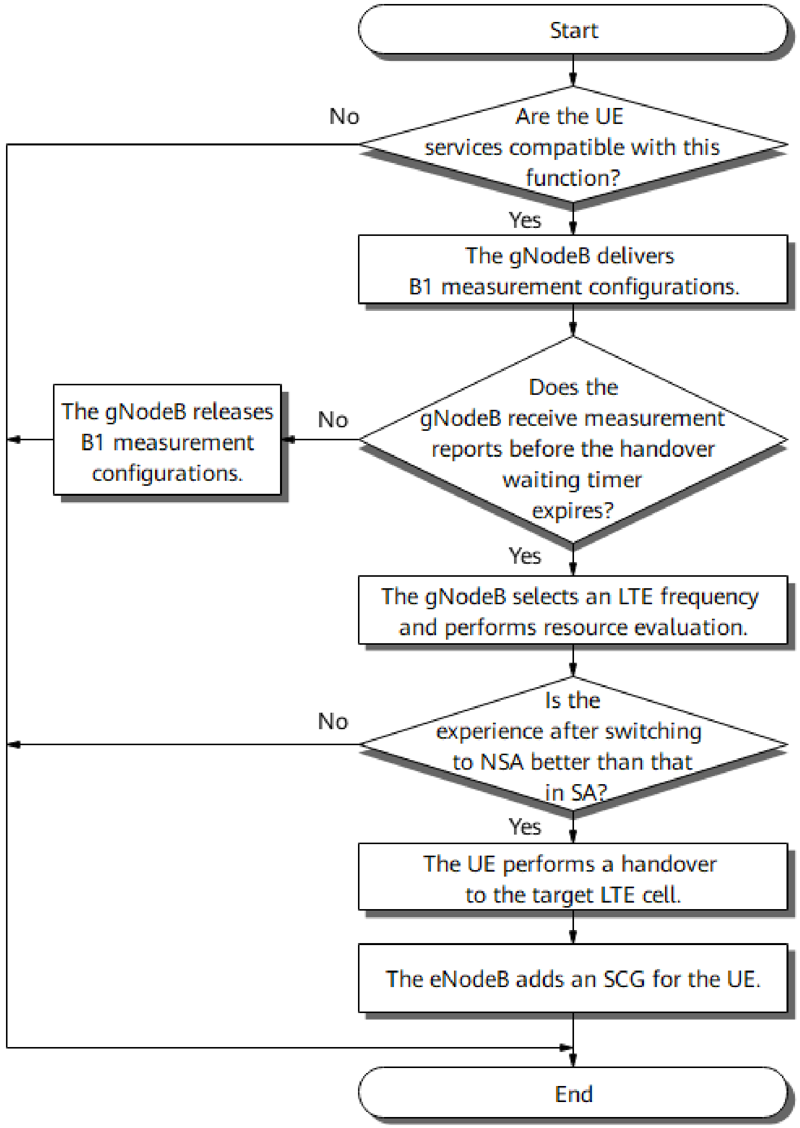
# SA-to-NSA Switching Based on Weak Uplink Coverage (Cont.)

- The gNodeB initiates SA-to-NSA switching based on user experience for identified UEs under weak uplink coverage.



# NSA-to-SA Switching Based on Strong Uplink Coverage

This function includes two steps:

- The gNodeB identifies UEs under strong uplink coverage. The differences between this function and the gNodeB identifying UEs under weak uplink coverage are as follows:
  - All UEs are initially in the weak coverage state.
  - If the SINR of a UE is found to be greater than the **NRDUCellSrsMeas**.EutranToNrSinrHighThld parameter value plus 2 dB for five consecutive times, the UE is considered to have entered the strong coverage state. Otherwise, the UE remains in the weak coverage state.

# NSA-to-SA Switching Based on Strong Uplink Coverage (Cont.)

- The gNodeB initiates NSA-to-SA switching based on user experience for the UEs under strong uplink coverage.
  1. The gNodeB delivers A1 measurement configurations to check the signal quality of the serving NR cell.
     - If the gNodeB receives the A1 measurement reports, the signal quality of the NR cell is satisfactory. The gNodeB sends an X2 message to instruct the eNodeB to perform NSA-to-SA switching.
     - If the gNodeB does not receive A1 measurement reports, the signal quality of the NR cell is unsatisfactory. The procedure ends.
  2. After receiving the NSA-to-SA switching request message, the eNodeB performs a handover for the switching.

# Network Impacts of NSA/SA Selection Based on User Experience

- Benefits
  - This function decreases the Service Call Drop Rate (CU, Inactive) of NR cells.
  - The larger the LTE FDD cell bandwidth and the better the coverage, the better the uplink user experience after SA-to-NSA switching.
  - The benefits of this function are affected in scenarios where available resources in LTE cells are limited, for example, when handovers of a large number of UEs are initiated towards an LTE cell at the same time. In these scenarios, there will be an insignificant improvement in the uplink user experience after SA-to-NSA switching.



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# Network Impacts of NSA/SA Selection Based on User Experience (Cont.)

- Impacts
  - NR:
    - The downlink PRB usage of NR cells decreases.
    - The downlink traffic volume in NR cells decreases.
    - During SA-to-NSA switching, the UE throughput decreases for a period of time.
    - After a UE switches from SA to NSA, the UE transmit power decreases, affecting the uplink data rate of the UE at the NR cell edge.
    - This function reduces the proportion of UEs camping in SA networking.
  - On the LTE side:
    - The uplink and downlink PRB usage of LTE cells increases (if downlink data split is enabled).
    - The uplink and downlink traffic volume of LTE cells increases (if downlink data split is enabled).
    - The downlink PRB usage of NSA DC UEs increases.

# Network Impacts of NSA/SA Selection Based on User Experience (Cont.)

- Impacts
  - On the LTE side:
    - The uplink and downlink PRB usage of LTE cells increases (if downlink data split is enabled).
    - The uplink and downlink traffic volume of LTE cells increases (if downlink data split is enabled).
    - The downlink PRB usage of NSA DC UEs increases.

# Feature Deployment of NSA/SA Selection Based on User Experience

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations, and DBS3900 and DBS5900 LampSite base stations<br>• Boards<br>For LTE, all boards that support NSA networking support this function. For NR, all NR-capable boards support this function.<br>• RF Modules<br>None |
| **Software Requirements** | • Prerequisite Functions<br>EPC-based NSA networking (NR and LTE sides)<br>• Mutually Exclusive Functions<br>Experience-based smart carrier selection (NR side) |
| **Network Requirements** | None |
| **NE Requirements** | • UEs must comply with 3GPP Release 15 or later.<br>• Core network requirements: The core networks must comply with 3GPP Release 15 or later. The N26 interface must be already configured between the MME and AMF. |

# Feature Deployment of NSA/SA Selection Based on User Experience (Cont.)

- License
  - Feature licenses

| RAT | Feature ID | Feature Name | Model | NE | Sales Unit |
|---|---|---|---|---|---|
| LTE FDD | MRFD-171222 | NSA/SA Selection Based on User Experience (LTE FDD) | LT1S0NSASA00 | eNodeB | per eNodeB |
| NR | MRFD-171262 | NSA/SA Selection Based on User Experience (NR) | NR0S0NSBUE00 | gNodeB | per base station |

# Feature Deployment of NSA/SA Selection Based on User Experience (Cont.)

- Activation on the NR side
  - //Enabling NSA/SA selection based on uplink coverage (This is a high-risk MML command.)
    - MOD GNODEBPARAM: NetworkingOptionOptSw=NSA_SA_UL_SEL_OPT_SW-1, NsaSaSelOptPeriod=60;ADD GNBOPERATOR: OperatorId=1, OperatorName="PRIMARY OPERATOR", Mcc="460", Mnc="00", OperatorType=PRIMARY_OPERATOR, NrNetworkingOption=SA_NSA, OperatorInterRatPolicySw=NSA_SA_UL_SEL_OPT_SW-1;
  - //Setting the network architecture selection policies for different QCIs.
    - MOD GNBQCIBEARER: Qci=1, NetworkingOptionOptFlag=FORBID;MOD GNBQCIBEARER: Qci=9, NetworkingOptionOptFlag=PERMIT;

# Feature Deployment of NSA/SA Selection Based on User Experience (Cont.)

- Activation on the LTE side
  - //Enabling NSA/SA selection based on uplink coverage
    - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_FDD_NSA_SA_UL_SEL_OPT_SW-1, NrHandoverAlgoSwitch=DIRECT_NR_HO_TO_EN_DC_SW-1;
  - //Setting the network architecture selection policies for different QCIs. The policies must be consistent with those configured on the gNodeB. Otherwise, a ping-pong effect will occur. (This is a high-risk MML command.)
    - MOD CNOPERATORQCIPARA: CnOperatorId=1, Qci=1, ServiceHoNrPolicyGroupId=0;
    - MOD CNOPERATORQCIPARA: CnOperatorId=1, Qci=9, ServiceHoNrPolicyGroupId=1;
    - MOD SERVICEIRHOCFGGROUP: CnOperatorId=1, ServiceIrHoCfgGroupId=0, InterRatHoState=NO_HO;
    - MOD SERVICEIRHOCFGGROUP: CnOperatorId=1, ServiceIrHoCfgGroupId=1, InterRatHoState=PERMIT_HO;



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# Feature Verification of NSA/SA Selection Based on User Experience

Trace the following interfaces in sequence and observe the signaling messages over the interfaces.

| NE | Interface Tracing | Using Signaling |
|---|---|---|
| gNodeB | X2 Interface Trace | If X2 messages include an EN-DC Private Evaluation Request message that carries the Evaluation Direction Indication field, the resource evaluation request message for NSA/SA selection based on uplink coverage has been successfully sent. |
| | Uu Interface Trace | If the value of the *targetRAT-Type* IE in the MobilityFromNRCommand message sent by the gNodeB to the relevant UE is "eutra", the preparation for the handover from NG-RAN to E-UTRAN has succeeded. |
| | NG Interface Trace | If the gNodeB receives a UE CONTEXT RELEASE COMMAND message from the AMF, the handover from NG-RAN to E-UTRAN has been successfully executed. |
| eNodeB | X2 Interface Trace | If there is an SgNB Addition Request Acknowledge message, an SCG has been successfully added. |

# Q&A

1. Which of the following functions are included in NSA/SA selection based on uplink coverage?

   A. Downlink low traffic

   B. Downlink high traffic

   C. Uplink weak coverage

   D. Strong uplink coverage

# Summary

- NSA/SA selection based on user experience: Added NSA/SA selection based on uplink coverage
  - SA-to-NSA switching based on weak uplink coverage
    - The gNodeB identifies UEs under weak uplink coverage.
    - The gNodeB initiates SA-to-NSA switching for the identified UEs under weak uplink coverage.
  - NSA-to-SA switching based on strong uplink coverage
    - The gNodeB identifies UEs under strong uplink coverage.
    - The gNodeB initiates NSA-to-SA switching for the identified UEs under strong uplink coverage.

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## 2. Optional Features







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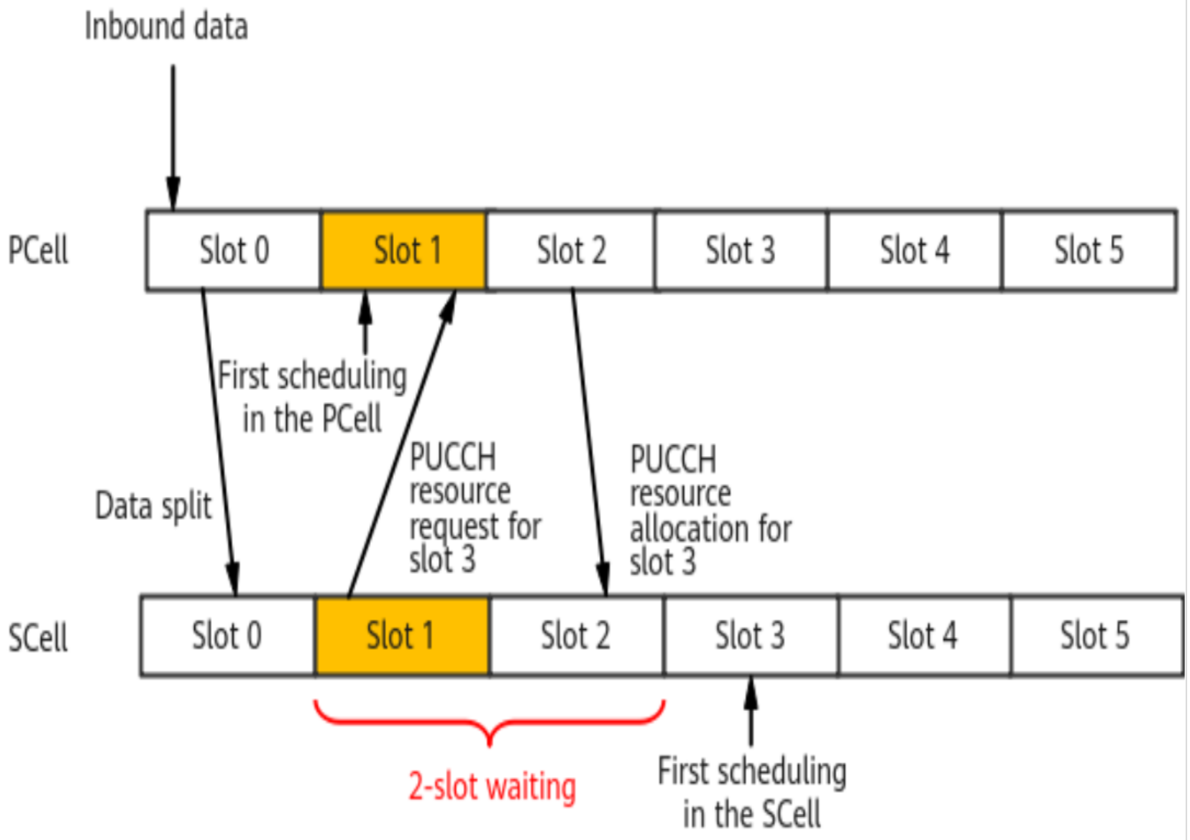
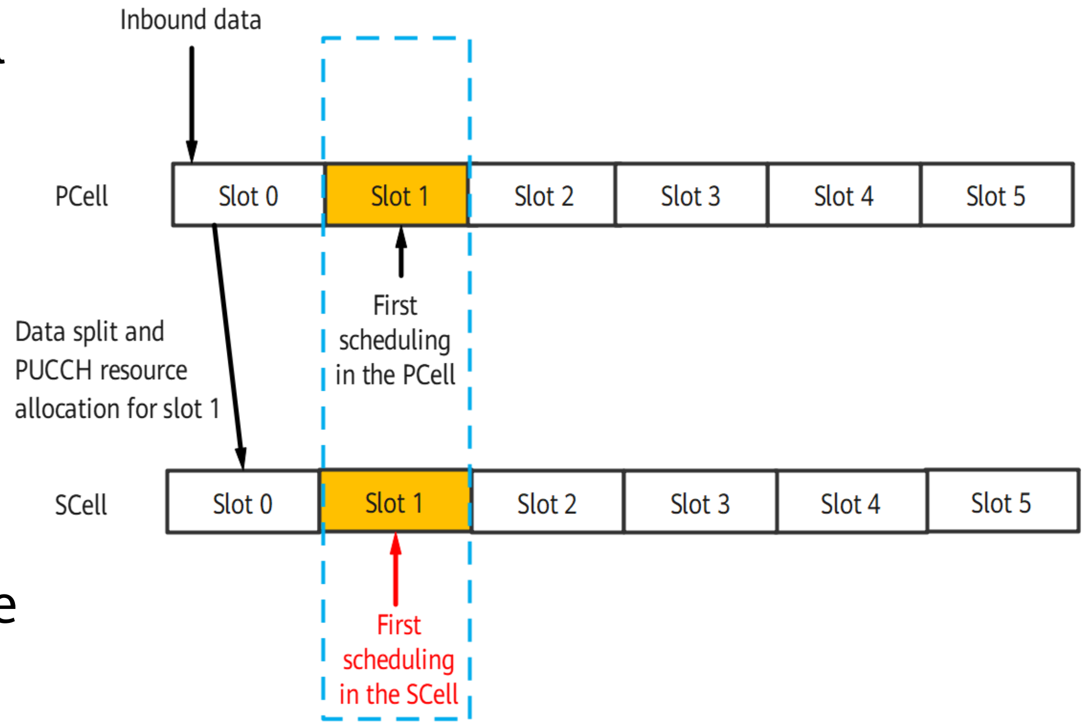
# Background of Fast CA




- Without fast CA:
  - Pcell indicate data ratio to Scell
  - Scell need to apply PUCCH resource for HARQ feedback
  - Pcell allocates PUCCH resource to Scell
  - Scell start the first scheduling
- It will cause at least 2slots delay for Scell first scheduling

# Fast CA Solution

- The base station serving the PCell allocates PUCCH resources to an activated SCell when distributing buffered RLC data to the SCell. In this way, the SCell does not have to request PUCCH resources from the PCell, enabling data transmission to start simultaneously in the PCell and SCell for better CA user experience.
- Fast CA is controlled by the **CA_ULTRA_LOW_LATENCY_SPLIT_SW** option of the **NRDUCellCarrMgmt**.CaEnhancedAlgoExtSwitch parameter.



# Fast CA Network Analysis

- Benefits
  - After Fast CA is enabled, the average throughput of SCell-activated CA UEs increases by 1% to 10% depends on traffic characters
  - The longer the continuous scheduling duration, the smaller the increase. In full buffer scenarios, there may be no increase
  - The first packet on Scell may reduced

# Fast CA Network Analysis (Cont.)

- Impacts
  - After Fast CA is enabled, the sizes of tail packets in the PCell and SCells may change. As the MCS indexes for small packets are lowered, the average MCS indexes in the PCell and SCells change.
  - After Fast CA is enabled, the PCell distributes data to SCells and allocates PUCCH resources for SCell data transmission in advance. As a result, the PCell throughput (N.ThpVol.DL.Cell/N.ThpTime.DL.Cell) decreases, and the average cell throughput of the entire network changes. In addition, as scheduling starts earlier in an SCell, the average number of scheduled UEs (N.User.Schedule.Dl.Sum/N.ThpTime.DL.Cell x 1000) changes.



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# Fast CA Feature Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>All NR-capable main control boards and baseband processing units support this feature.<br>• RF Modules<br>All NR-capable RF modules support this feature. |
| **Software Requirements** | • Prerequisite Functions<br>Intra-band CA<br>Intra-FR inter-band CA<br>• Mutually Exclusive Functions<br>None |
| **Networking Requirements** | • Fast CA does not take effect in NR SUL cells, for which the **NRDUCell**.DuplexMode parameter is set to **CELL_SUL**.<br>• Fast CA does not take effect in hyper cells or combined cells, for which **NRDUCell**.NrDuCellNetworkingMode is set to **HYPER_CELL** or **HYPER_CELL_COMBINE_MODE**, respectively. |
| **NE Requirements** | This feature is implemented on the gNodeB. |



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# Fast CA Feature Deployment (Cont.)

- Licenses
  - Feature licenses

| Feature ID | RAT | Feature Name | Model | NE | Sales Unit |
|---|---|---|---|---|---|
| FOFD-061224 | NR FDD<br>Low-frequency NR TDD | Fast CA | NR0S0FASTCA0 | Macro gNodeB | per Cell |



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# Fast CA Feature Deployment (Cont.)

- Activation
  - //Enabling Fast CA
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoExtSwitch=CA_ULTRA_LOW_LATENCY_SPLIT_SW-1;
  - //(Optional) Enabling fast SCell activation
    - MOD NRDUCELLUEPWRSAVING: NrDuCellId=0, BwpPwrSavingSw=BWP2_SWITCH-0;
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaDlScellActThldSlotNum=0, CaDlScellDeactThldSlotNum=0;



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# Fast CA Feature Deployment (Cont.)

- Deactivation
  - //Disabling Fast CA
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoExtSwitch=CA_ULTRA_LOW_LATENCY_SPLIT_SW-0;
  - //(Optional; low-frequency NR TDD) Disabling fast SCell activation
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaDlScellActThldSlotNum=16, CaDlScellDeactThldSlotNum=4;
  - //(Optional; NR FDD) Disabling fast SCell activation
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaDlScellActThldSlotNum=8, CaDlScellDeactThldSlotNum=2;



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# Fast CA Feature Verification

- Activation verification
  - If the average throughput of CA SCell-activated UEs increases after Fast CA is enabled, Fast CA has taken effect. This average throughput is calculated using the following formula: (N.CA.SccActiveUser.ThpVol.DL – N.CA.ThpVol.DL.LastSlot)/N.CA.ThpTime.DL.RmvLastSlot.

# Fast CA Feature Verification (Cont.)

- Network monitoring
  - Observe the average downlink UE throughput to check whether the UE data rate increases after this feature is enabled.
    - Average downlink UE throughput: User Downlink Average Throughput (DU)
  - Observe the RLC traffic volume to CA UEs in a cell, that is, the total volume of downlink data sent at the RLC layer in a cell to SCell-activated CA UEs.
    - RLC traffic volume to CA UEs in a cell = N.CA.SccActiveUser.ThpVol.DL
  - Observe the average throughput of SCell-activated CA UEs, which is calculated using the following formula: (N.CA.SccActiveUser.ThpVol.DL – N.CA.ThpVol.DL.LastSlot)/N.CA.ThpTime.DL.RmvLastSlot.



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# Section Summary

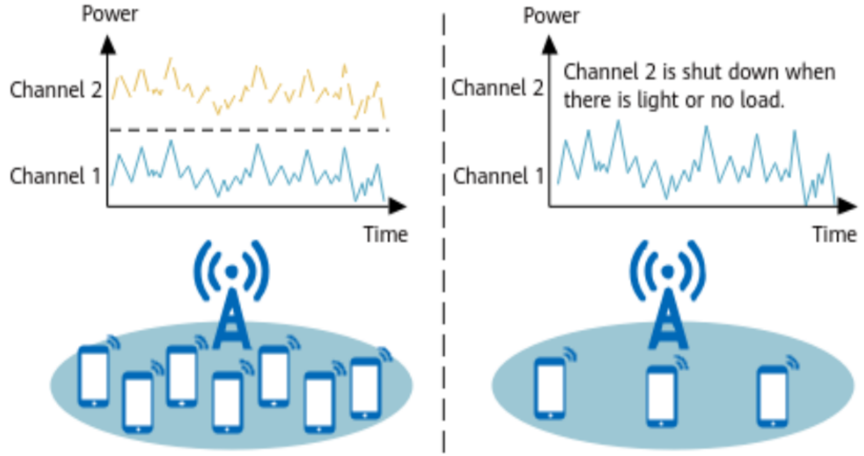
- With Fast CA introduced to this version, the base station serving the PCell allocates PUCCH resources to an activated SCell when distributing buffered RLC data to the SCell. In this way, the SCell does not have to request PUCCH resources from the PCell, enabling data transmission to start simultaneously in the PCell and SCell for better CA user experience. This feature applies to macro and LampSite base stations and works in FDD and low-frequency TDD.

# Contents

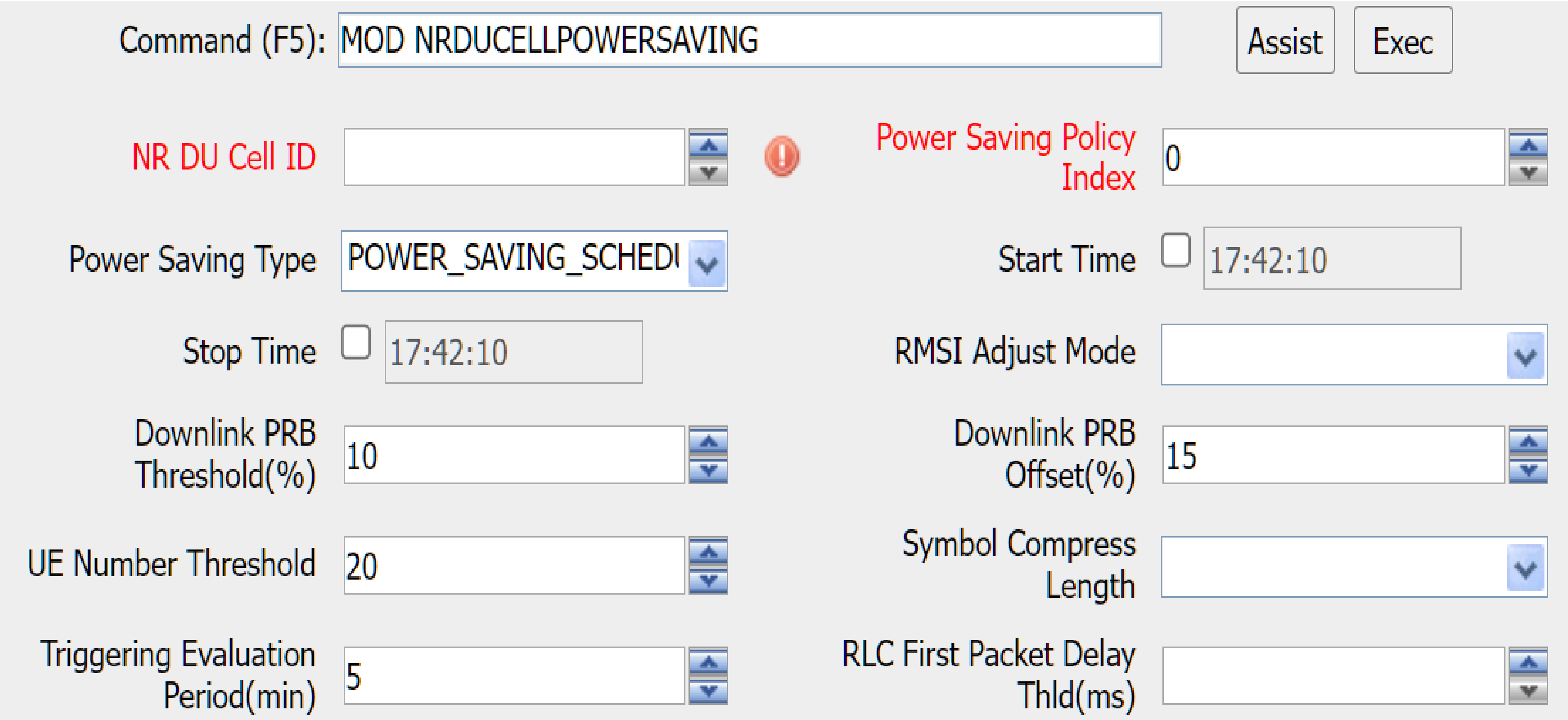
## 2. Optional Features

# RF Channel Intelligent Shutdown Overview

- RF channel intelligent shutdown enables a base station to automatically shut down some transmit channels of a cell when the network is under light or no load during preset periods
  - RF channel intelligent shutdown is triggered by UE number and PRB ratio evaluation
  - A macro base station shuts down half of the transmit channels of a cell by default. A LampSite base station can shut down three out of four RF channels of a 4T cell or one out of two RF channels of a 2T cell



# Key Parameters of RF Channel Shutdown



# RF Channel Intelligent Shutdown Enhancement

- RF channel intelligent shutdown enhancement includes:
  - Parameter control over the triggering evaluation period for RF channel intelligent shutdown
    - The **NRDUCellPowerSaving.**ShutdownTrigJudgePeriod parameter specifies the triggering evaluation period indicated by an energy saving policy index. Entry into or exit from an energy saving feature is triggered for a cell if this cell meets entering or exiting conditions in this period.
  - Optimization of the relationships between RF channel intelligent shutdown and other functions
  - Compatibility of RF channel intelligent shutdown with additional beam coverage scenarios and RF modules
  - Shortened wait time for RF channel intelligent shutdown to take effect in multi-carrier scenarios
  - Change of the cell bandwidth requirement of RF channel intelligent shutdown to 40 MHz or higher in low-frequency TDD scenarios



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# RF Channel Intelligent Shutdown Feature Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>NR-capable main control boards and baseband processing units<br>• RF Modules<br>RRU/AAU: See the RF module requirements of RF channel intelligent shutdown in Energy Conservation and Emission Reduction Feature Parameter Description.<br>pRRU: All NR TDD-capable 4T4R or 2T2R pRRUs support this feature. |
| **Software Requirements** | • Prerequisite Functions<br>None<br>• Mutually Exclusive Functions<br>Hyper Cell, Cell Combination, Extended Cell Range, Hybrid DSS Based on Asymmetric Bandwidth, and distributed massive MIMO |
| **Network Requirements** | None |
| **NE Requirements** | This feature is implemented on the gNodeB. |

# RF Channel Intelligent Shutdown Feature Deployment (Cont.)

- Licenses
  - Feature licenses

| Feature ID | RAT | Feature Name | Model | NE | Sales Unit |
|---|---|---|---|---|---|
| FOFD-031205 | NR TDD<br>NR FDD | RF Channel Intelligent Shutdown | NR0S00RCIS00 | gNodeB | per Cell |



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# RF Channel Intelligent Shutdown Feature Verification

- Network monitoring
  - Energy consumption data for base stations can be obtained by using the counter VS.EnergyCons.BTS.Adding.NR (for a base station) or VS.EnergyCons.BTSBoard (for RF modules) on the MAE-Access.
  - The RF channel shutdown duration caused by the activation of this function can be obtained by using the N.PowerSaving.RFShutdown.Dur counter on the MAE-Access.

# RF Channel Intelligent Shutdown Feature Deployment (Cont.)

- Activation

  //Enabling RF channel intelligent shutdown

  MOD NRDUCELLALGOSWITCH: NrDuCellId=0, PowerSavingSwitch=RF_SHUTDOWN_SW-1;

  //Setting an energy saving policy of RF channel intelligent shutdown for an NR TDD cell

  ADD NRDUCELLPOWERSAVING: NrDuCellId=0, PowerSavingPolicyIndex=0, StartTime=01&00&00, StopTime=03&00&00, PowerSavingType=RF_SHUTDOWN, DlPrbThld=10, DlPrbOffset=15, UserNumThld=20, UserNumOffset=20, CovCompensationMode=AUTO;

  //Setting an energy saving policy of RF channel intelligent shutdown for an NR FDD cell

  ADD NRDUCELLPOWERSAVING: NrDuCellId=0, PowerSavingPolicyIndex=0, StartTime=01&00&00, StopTime=03&00&00, PowerSavingType=RF_SHUTDOWN, DlPrbThld=5, DlPrbOffset=15, UserNumThld=20, UserNumOffset=20, CovCompensationMode=AUTO;

# RF Channel Intelligent Shutdown Feature Verification

- Activation verification
  - Method 1:
    1. Run the **LST NRDUCELLALGOSWITCH** command. If the value of the **Power Saving Switch** parameter is **RF Channel Power Saving Switch:On** in the command output, RF channel intelligent shutdown has been enabled.
    2. Run the **LST NRDUCELLPOWERSAVING** command. Verify that there is at least one record with **Power Saving Type** being **RF Channel Power Saving**.
    3. Run the **DSP TIME** command. Check whether the system time is within a period for RF channel intelligent shutdown.
       - If it is, go to step 4.
       - If it is not, wait until the start time of RF channel intelligent shutdown arrives.



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# RF Channel Intelligent Shutdown Feature Verification (Cont.)

- Activation verification
  - Method 1:
    4. Check whether the downlink PRB usage of the cell (which equals (N.PRB.DL.DrbUsed.Avg – N.PRB.DL.ExtendUsed.Avg)/N.PRB.DL.Avail.Avg) is less than or equal to the downlink PRB usage threshold for starting RF channel intelligent shutdown (specified by the **NRDUCellPowerSaving.**DlPrbThld parameter). In addition, check whether the number of RRC_CONNECTED UEs in the cell (indicated by N.User.RRCConn.Avg) is less than or equal to the UE number threshold for starting this function (specified by the **NRDUCellPowerSaving.**UserNumThld parameter).



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# RF Channel Intelligent Shutdown Feature Verification (Cont.)

- Activation verification
  - Method 1:
    - If they are, go to step 5.
    - If one or both are not, wait until the downlink PRB usage of the cell is less than or equal to the downlink PRB usage threshold for starting RF channel intelligent shutdown and the number of RRC_CONNECTED UEs in the cell is less than or equal to the UE number threshold for starting this function.

5. Wait for a certain period of time. Then, run the **DSP NRDUCELL** command. Verify that the value of **Power Saving State** is **RF Channel Power Saving:Enabled**, which indicates that RF channel intelligent shutdown has taken effect.





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# RF Channel Intelligent Shutdown Feature Verification (Cont.)

- Activation verification
  - Method 2:
    - Run the **DSP NRDUCELLPOWERSAVING** command to query the status of RF channel intelligent shutdown.
      - If the value of **Power Saving Type** is **RF Channel Power Saving** and the value of **Current State** is **Enabled**, RF channel intelligent shutdown has taken effect.
      - If the value of **Power Saving Type** is **RF Channel Power Saving** and the value of **Current State** is **Disabled**, you can check **Current Disabled Cause** to determine why RF channel intelligent shutdown has not taken effect.



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# RF Channel Intelligent Shutdown Feature Verification (Cont.)

- Network monitoring
  - Energy consumption data for base stations can be obtained by using the counter VS.EnergyCons.BTS.Adding.NR (for a base station) or VS.EnergyCons.BTSBoard (for RF modules) on the MAE-Access.
  - The RF channel shutdown duration caused by the activation of this function can be obtained by using the N.PowerSaving.RFShutdown.Dur counter on the MAE-Access.

# Q&A

1. (    ) MHz is the minimum required cell bandwidth for RF channel intelligent shutdown in low-frequency TDD scenarios?

   A. 10

   B. 20

   C. 40

   D. 100

# Section Summary

- RF channel intelligent shutdown enhancement includes:
  - Parameter control over the triggering evaluation period for RF channel intelligent shutdown
  - Optimization of the relationships between RF channel intelligent shutdown and other functions
  - Compatibility of RF channel intelligent shutdown with additional beam coverage scenarios and RF modules
  - Shortened wait time for RF channel intelligent shutdown to take effect in multi-carrier scenarios
  - Change of the cell bandwidth requirement of RF channel intelligent shutdown to 40 MHz or higher in low-frequency TDD scenarios

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## 2. Optional Features







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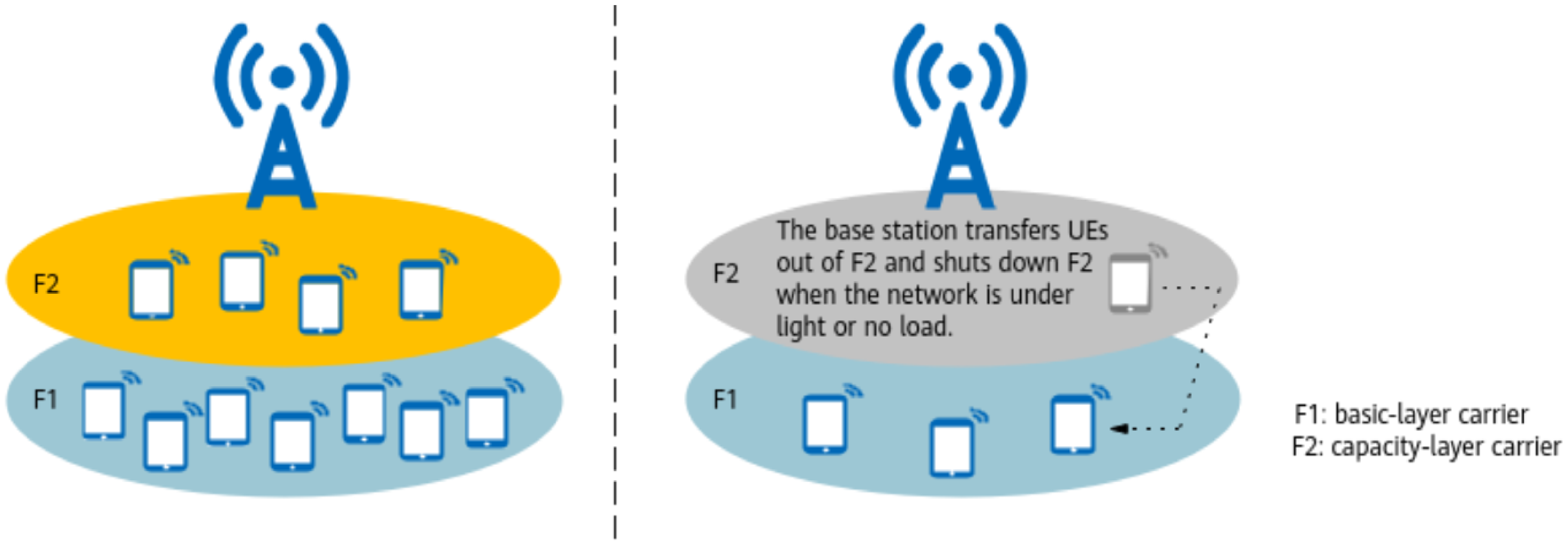
# Principle




- Intelligent carrier shutdown enables the base station to transfer UEs from capacity-layer cells to basic-layer cells and to shut down capacity-layer carriers when the network is under light or no load within specified periods

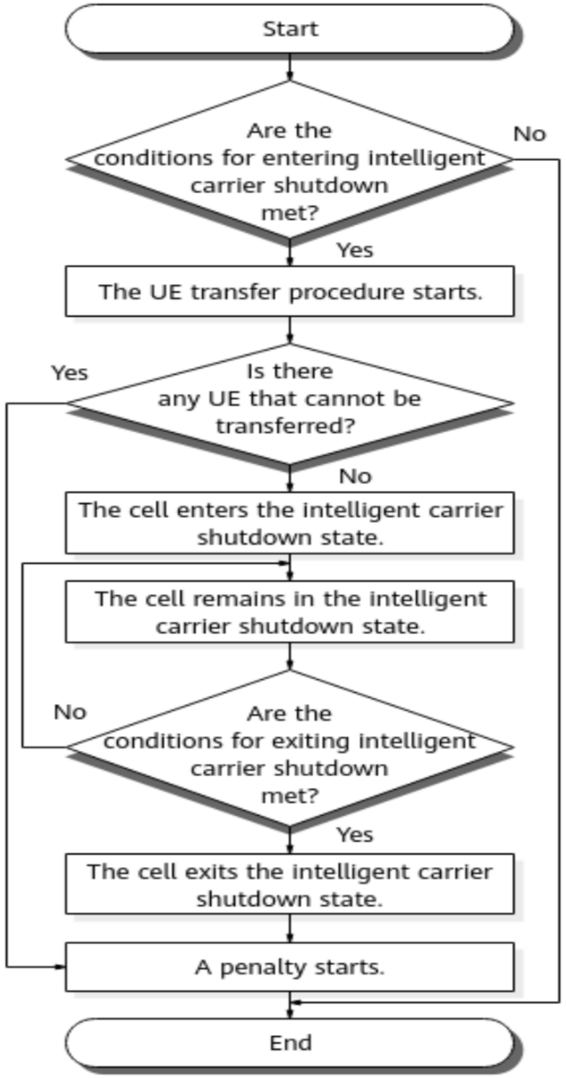
# Basic Layer & Capacity Layer Definition

- Basic-layer and capacity-layer cells are relative concepts identified by the **NRCellRelation**.*PowerSavingCellFlag* parameter during neighbor relationship configuration
  - If this parameter is set to **COVERAGE**, the neighboring cell is a basic-layer cell and the serving cell is a capacity-layer cell
  - If this parameter is set to **CAPACITY**, the neighboring cell is a capacity-layer cell and the serving cell is a basic-layer cell
  - If this parameter is set to **NOT_CONFIG**, neither the serving cell nor the neighboring cell is defined as a capacity-layer or basic-layer cell. The neighboring cell is not considered in intelligent carrier shutdown
- Note: one cell could be either basic layer or capacity layer corresponding with different neighbor cell

# Feature Enabled Procedure

- This function takes effect every day within the configured intelligent carrier shutdown periods under certain conditions. The periods, load threshold, and other information under an energy saving policy are specified by the parameters in the **NRDUCellPowerSaving** MO
  - The **NRDUCellPowerSaving.**_PowerSavingPolicyIndex_ parameter specifies an energy saving policy index. It uniquely identifies an energy saving policy within the local cell
  - The **NRDUCellPowerSaving.**_PowerSavingType_ parameter specifies the energy saving type indicated by an energy saving policy index. Intelligent carrier shutdown requires that this parameter be set to **INTRA_GNB_MULTI_CARR_SD** or **INTER_GNB_MULTI_CARR_SD**
  - For inter-gNB scenario, Xn interface should be deployed for information exchange
- All the parameters are defined in capacity layer cell only

# Intelligent Carrier Shutdown Procedure




- After intelligent carrier shutdown is enabled, the base station checks whether the conditions for entering intelligent carrier shutdown are met in a period specified by the **NRDUCellPowerSaving**.***ShutdownTrigJudgePeriod*** parameter. After intelligent carrier shutdown takes effect for a capacity-layer cell, the base station checks whether the conditions for exiting intelligent carrier shutdown are met at an interval of 1 minute

# Conditions for Entering Intelligent Carrier Shutdown

- All the following conditions should be met to trigger the carrier shut down
  - For capacity layer general requirement :
    - The current time is within the range specified for intelligent carrier shutdown
    - The capacity-layer cell is not in any energy saving penalty state
  - For basic layer general requirement
    - All basic-layer carriers are available
    - Some basic-layer carriers are available, while others, functioning as capacity-layer carriers of other basic-layer carriers, are in the intelligent carrier shutdown state



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# Conditions for Entering Intelligent Carrier Shutdown(*Cont.*)

- For the traffic requirements in capacity layer and basic layer
  - The total downlink/uplink PRB usage of the capacity-layer carrier and basic-layer carriers is less than or equal to the PRB usage threshold
    - PRB usage = (Number of PRBs used by  the capacity-layer carrier + Number of PRBs used by the basic-layer carriers)/Number of available PRBs of the basic-layer carriers(Downlink and uplink PRB usage will be calculated separately
  - The total number of RRC_CONNECTED UEs on the capacity-layer carrier and a basic-layer carrier is less than or equal to the UE number threshold
  - The Xn interface is in the normal state in multi-carrier inter-base-station scenarios



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# UE Transfer & Enter Carrier Shutdown

| Service type | UE transfer procedure | Limitation |
|---|---|---|
| SA | Trigger inter-frequency procedure | If there are voice service UEs that cannot be handed over from the capacity-layer cell due to the specific policy, intelligent carrier shutdown stops 30s. In addition, intelligent carrier shutdown cannot be triggered for the capacity-layer cell again within 30 minutes |
| | | For no voice UE, if handover is not supported, they can be transferred through redirection |
| NSA | UE connections on the NR side are released | None |

- Once all UEs are transferred out of the capacity-layer cell, no RRC_CONNECTED UEs remain in the cell, and the cell enters the intelligent carrier shutdown state



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# Conditions for Exiting Intelligent Carrier Shutdown

- A capacity-layer cell automatically exits the intelligent carrier shutdown state and cannot enter this state again within a period specified by the **NRDUCellPowerSaving**.*CarrShutdownPenaltyTime* parameter if any of the conditions listed below is met. If none of these conditions is met, the cell remains in the intelligent carrier shutdown state
  - The current time is not within the range specified for intelligent carrier shutdown
  - The total  PRB usage of basic-layer carriers is greater than the sum of the previous threshold plus the offset
  - The number of RRC_CONNECTED UEs served by a basic-layer carrier is greater than the sum of previous threshold plus offset
  - The Xn interface is in the abnormal state in multi-carrier inter-base-station scenarios
  - Any of basic laer cell become unavailable

# Key Parameters Introduction

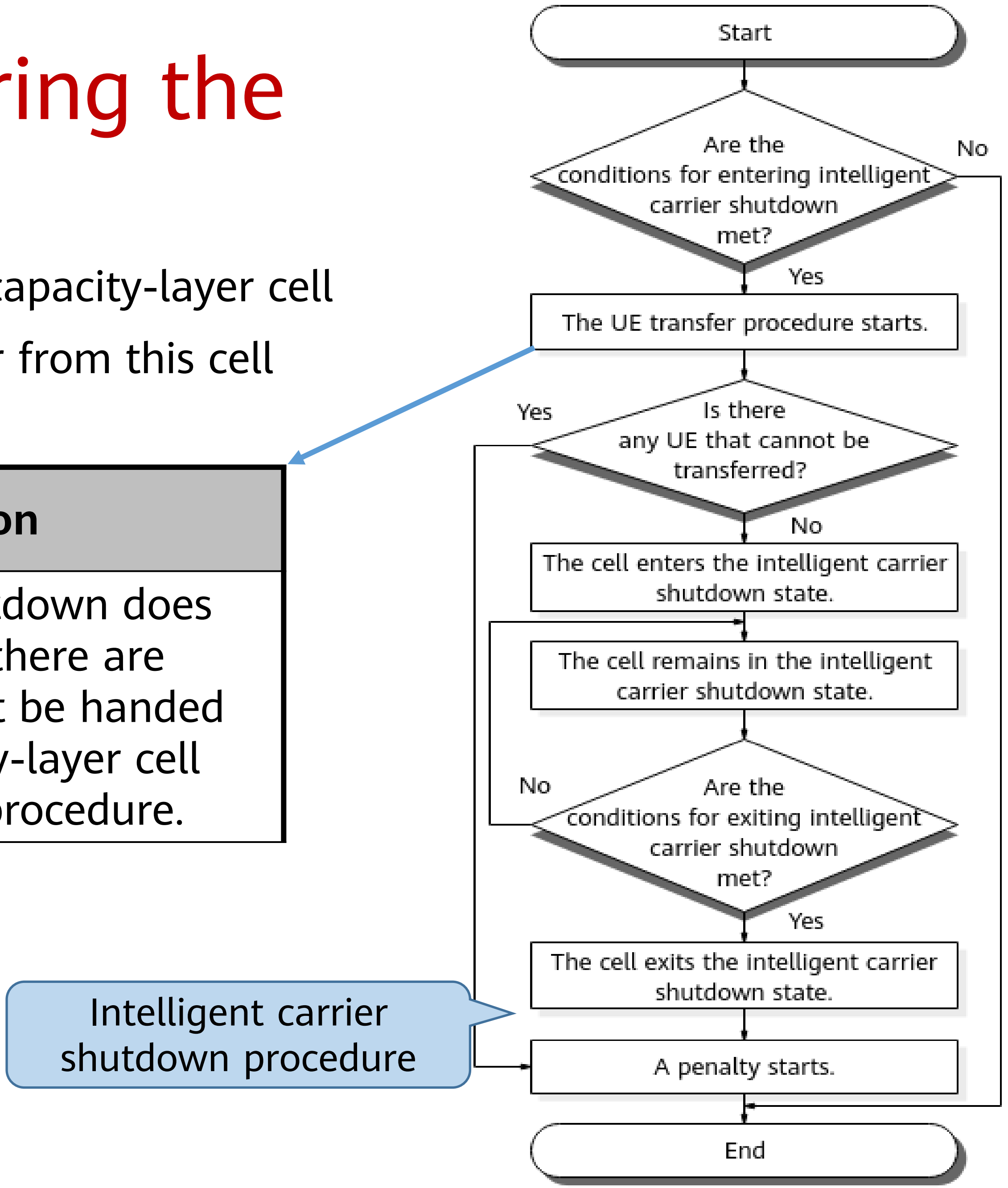
Command (F5): MOD NRDUCELLPOWERSAVING   Assist   Exec

| | | | |
|---|---|---|---|
| NR DU Cell ID | | Power Saving Policy Index | 0 |
| Power Saving Type | INTER_GNB_MULTI_CARI | Start Time | 00:00:00 |
| Stop Time | 06:00:00 | Downlink PRB Threshold(%) | 25 |
| Downlink PRB Offset(%) | 25 | UE Number Threshold | 20 |
| Power Saving Penalty Time(min) | 30 | User Number Offset | 20 |
| Triggering Evaluation Period(min) | 5 | Uplink PRB Threshold(%) | 30 |
| Neighboring Cell Uplink PRB Offset(%) | 25 | | |

# Protection for VoNR UEs During the UE Transfer Procedure

- Intelligent carrier shutdown does not take effect in a capacity-layer cell when there are VoNR UEs that cannot be handed over from this cell during a UE transfer procedure.

| Function Switch | Description |
|---|---|
| **VONR_SW** option of the **NRCellAlgoSwitch.VonrSwitch** parameter | Intelligent carrier shutdown does not take effect when there are VoNR UEs that cannot be handed over from the capacity-layer cell during a UE transfer procedure. |



# Support for Determination Based on Uplink PRB Usage

- The uplink PRB usage of the local cell and that of neighboring cells are considered for determining whether to enter or exit the intelligent carrier shutdown state.

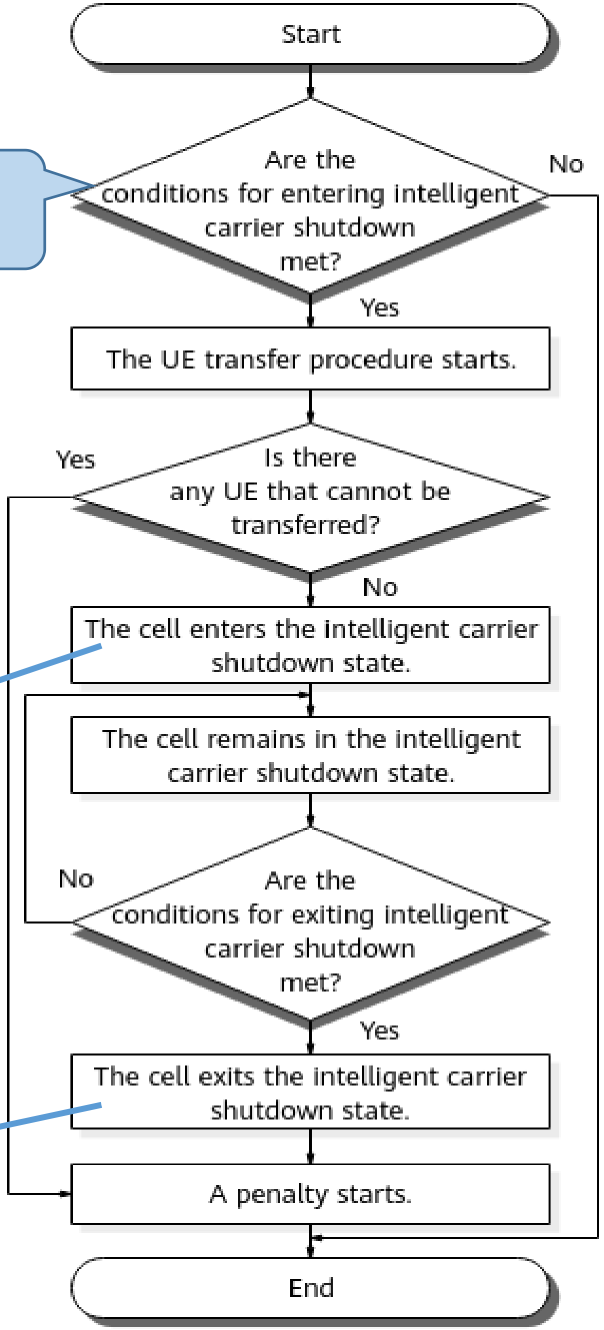
One of the condition of enter the intelligent carrier shutdown state:

- The total uplink PRB usage of the capacity-layer carrier and basic-layer carriers is less than or equal to the uplink PRB usage threshold specified by the **NRDUCellPowerSaving.UlPrbThld** parameter, where

One of the condition of exits the intelligent carrier shutdown state:

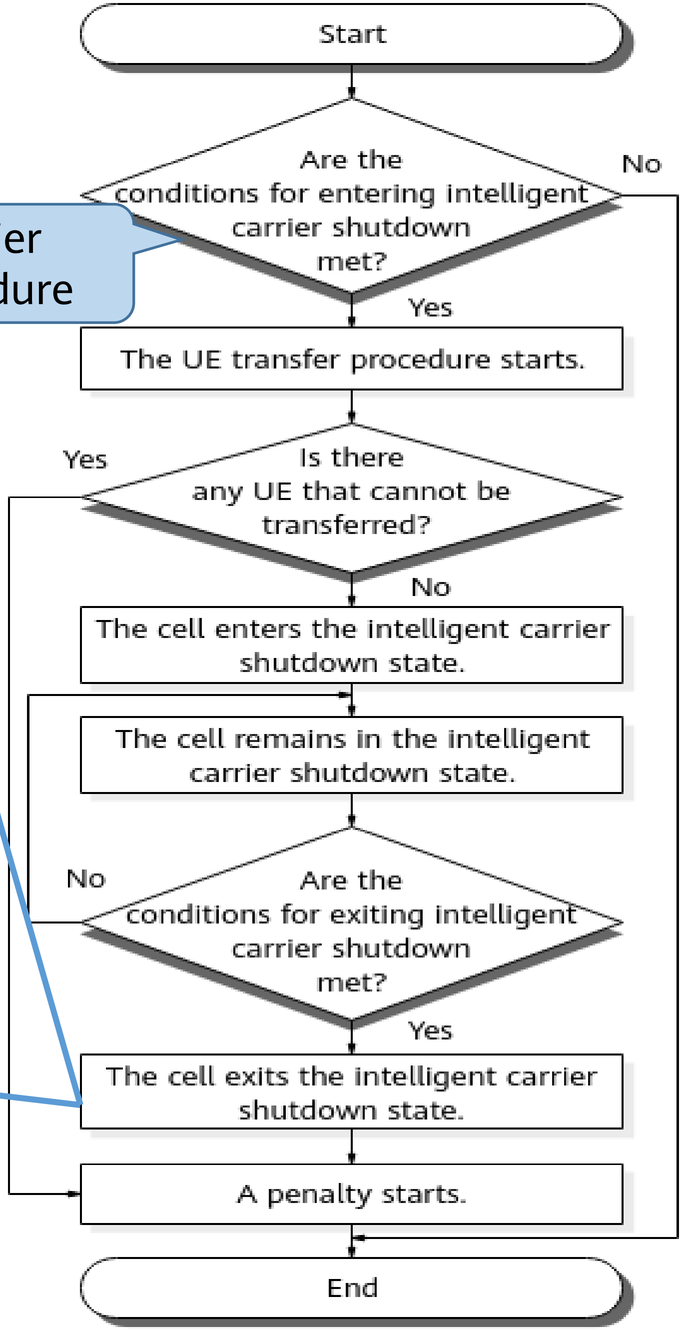
- The total uplink PRB usage of basic-layer carriers is greater than the sum of the **NRDUCellPowerSaving.UlPrbThld** and **NRDUCellPowerSaving.NCellUlPrbOffset** parameter values.

Intelligent carrier shutdown procedure



# Parameter Optimization for Intelligent Carrier Shutdown

Intelligent carrier shutdown procedure




- A capacity-layer cell automatically exits the intelligent carrier shutdown state and cannot enter this state again within a period specified by the **NRDUCellPowerSaving.CarrShutdownPenaltyTime** parameter if any of the conditions is met.

One of the condition of exits the intelligent carrier shutdown state：

- The number of RRC_CONNECTED UEs served by a basic-layer carrier is greater than the sum of the **NRDUCellPowerSaving.UserNumThld** and **NRDUCellPowerSaving.UserNumOffset** parameter values.





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# Intelligent Carrier Shutdown Enhancement

- In versions earlier than V100R018C00, periodic measurement configurations for intelligent carrier shutdown cannot be delivered to UEs that have received other periodic measurement configurations.
- In this version, this issue has been resolved so that periodic measurement configurations for intelligent carrier shutdown can be delivered to such UEs.
  - With intelligent carrier shutdown, periodic measurement configurations are delivered to selected UEs.
  - The measurement results containing the adjacent coverage conditions are sent to the OSS.
  - The OSS then uses the measurement results to generate power saving cell flag suggestions.
  - The base station performs operations related to carrier shutdown based on the suggestions from the OSS.
- Impact on the Network
  - The change in this feature brings additional periodic measurement tasks for specified UEs, which may slightly decrease the user-perceived rate.



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# Optimized Processing When Both Intelligent Carrier Shutdown and LTE and NR Intelligent Carrier Shutdown

- In versions earlier than V100R018C10, in a scenario where any two or all of intra-base-station intelligent carrier shutdown, inter-base-station intelligent carrier shutdown, and LTE and NR intelligent carrier shutdown are enabled for a cell.
  - this cell enters the carrier shutdown state if the entering conditions of any of the enabled functions are met within the overlapping range of the configured effective periods for these functions.
- In V100R018C10 or later versions, the processing in this scenario has been optimized. The cell enters the carrier shutdown state only if the entering conditions of **all the enabled** functions are met within the overlapping range of the configured effective periods of these functions.

| Function Switch | Description |
|---|---|
| **LNR_SMART_CARRIER_SHUTDOWN_SW** option of the **NRDUCellAlgoSwitch.PowerSavingSwitch** parameter | When both intelligent carrier shutdown and LTE and NR intelligent carrier shutdown are enabled for a cell, this cell enters the carrier shutdown state only if the entering conditions for both functions are met. |

# Feature Benefits

- When RATs do not share RF modules, about 35% gains are obtained when massive MIMO takes effect with 64T/32T TDD modules, and about 50% gains are obtained when the feature takes effect with 4T/2T FDD RRUs. The deviation of gains is no more than 10%.

# Intelligent Carrier Shutdown Feature Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• All boards and RF modules support this featue |
| **Software Requirements** | • Prerequisite Functions<br>None<br>• Mutually Exclusive Functions<br>Timing carrier shutdown & low latency and high reliability |
| **Network Requirements** | None |
| **NE Requirements** | This feature is implemented on the gNodeB |
| **License Requirements** | FOFD-050203 Intelligent Carrier Shutdown |



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# Deployment – Activation

//Turning on the switch for LTE and NR intelligent carrier shutdown

- MOD NRDUCELLALGOSWITCH: NrDuCellId=1, PowerSavingSwitch=LNR_SMART_CARRIER_SHUTDOWN_SW-1;

//(Optional, required only in SA networking) Configuring all overlapping neighboring cells with the parameters set as follows: MCC is 460, MNC is 01, and eNodeB ID is 441282.

- MOD NRCELLEUTRANRELATION: NrCellId=1, Mcc="460", Mnc="01", EnodebId=441282, CellId=0, PowerSavingOverlapInd=LNR_CARR_SHUTDOWN_OVERLAP_IND-1;

//Adding power saving configurations

- ADD NRDUCELLPOWERSAVING: NrDuCellId=1, PowerSavingPolicyIndex=0, StrtTime=00&00&00, StopTime=06&00&00,PowerSavingType=LNR_SMART_CARRIER_SHUTDOWN, DlPrbThld=5, UlPrbThld=5, UserNumThld=20, CarrShutdownPenaltyTime=30, EutranDlPrbThld=30, EutranDlPrbOffset=30, NCellUlPrbThld=30, NCellUlPrbOffset=30,EutranCarrShutdownRatio=90, EutranCarrShutadownExitOfs=70, EutranNrUserNumThld=20, EutranNrUserNumThldOfs=20, EutranNrUserDlPrbThld=15, EutranNrUserDlPrbThldOfs=15, EutranNrUserUlPrbThld=15, EutranNrUserUlPrbThldOfs=15, ShutdownTrigJudgePeriod=1;



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# Deployment – Deactivation

//Turning off the switch for LTE and NR intelligent carrier shutdown

- MOD NRDUCELLALGOSWITCH: NrDuCellId=1, PowerSavingSwitch=LNR_SMART_CARRIER_SHUTDOWN_SW-0;

//(Optional, required only in SA networking) Removing all neighbor relationships for power saving in the overlapping coverage area

- MOD NRCELLEUTRANRELATION: NrCellId=0, Mcc="460", Mnc="01", EnodebId=441282, CellId=0, PowerSavingOverlapInd=LNR_CARR_SHUTDOWN_OVERLAP_IND-0;

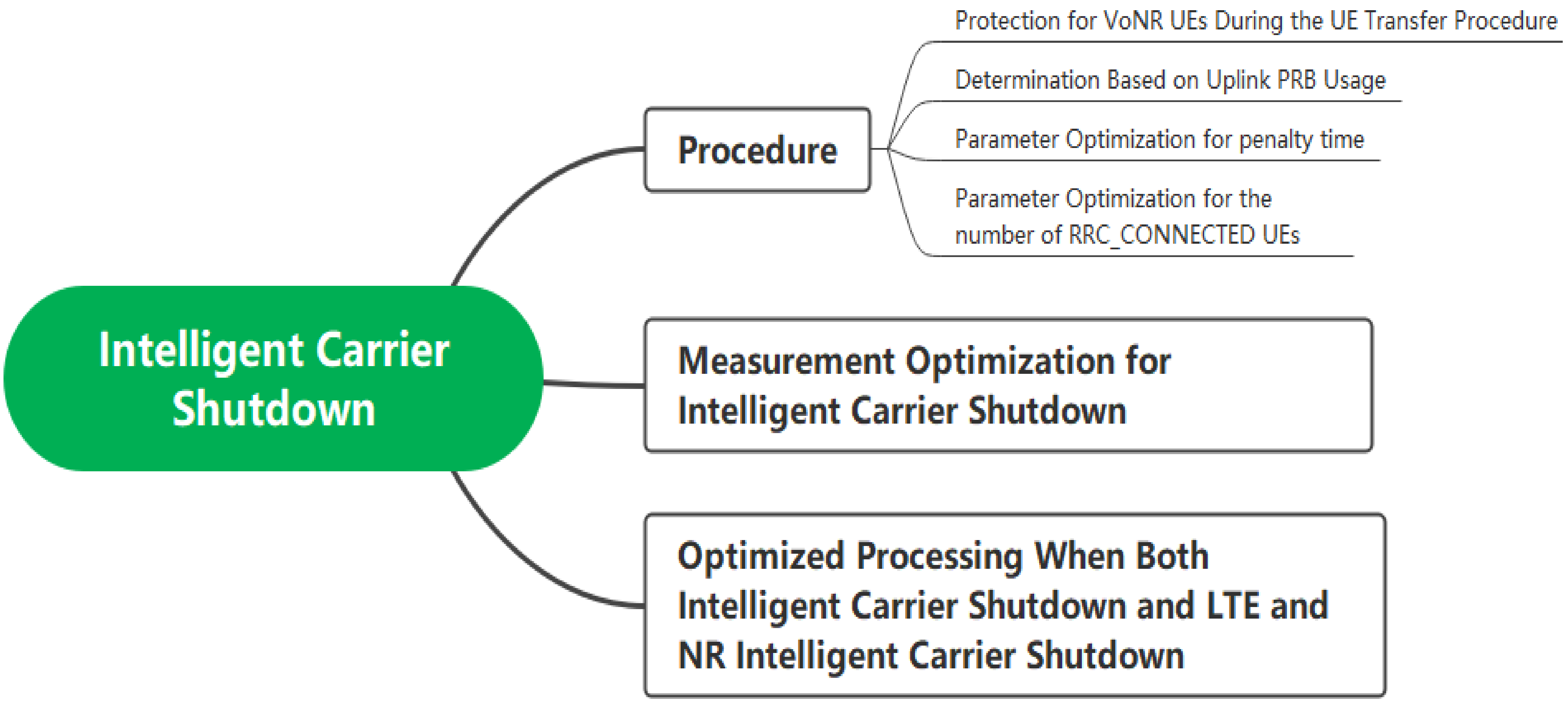
//Removing power saving configurations

- RMV NRDUCELLPOWERSAVING: NrDuCellId=1, PowerSavingPolicyIndex=0;

# Network Monitoring for Relevant KPI

- Energy consumption data for base stations can be obtained by using the counter VS.EnergyCons.BTS.Adding.NR (for a base station) or VS.EnergyCons.BTSBoard (for RF modules)
- The duration of cell unavailability due to intelligent carrier shutdown can be obtained using the N.Cell.Unavail.Dur.EnergySaving counter
- The duration in which the cell stays in the carrier shutdown state due to intelligent carrier shutdown can be obtained using the N.PowerSaving.CarrierShutdown.Dur counter

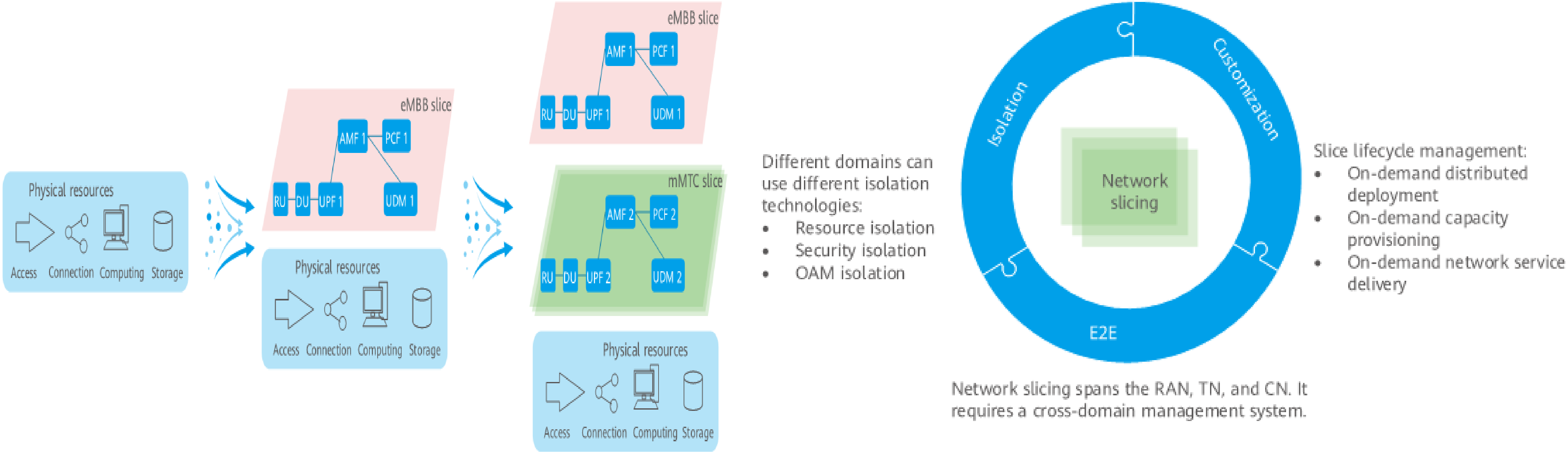
# Section Summary



# Contents

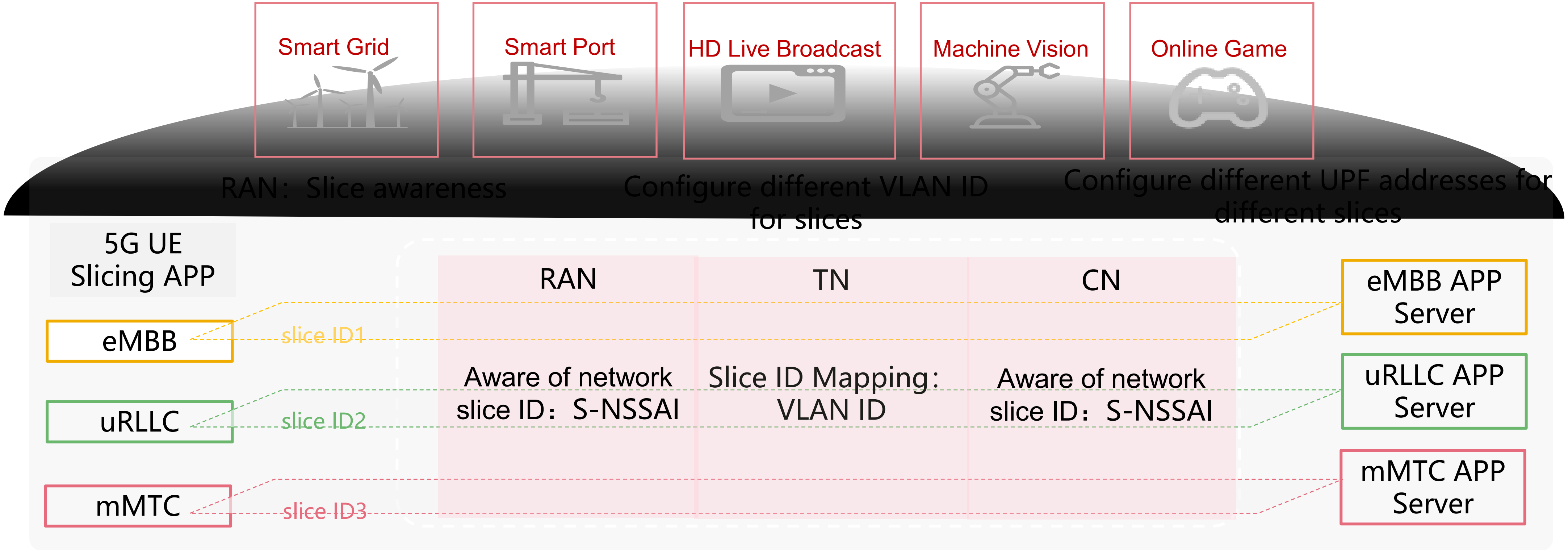
## 2. Optional Features

# Definition of Network Slicing




- Network slicing is a technology that enables operators to virtualize a physical network into multiple E2E networks on top of the same hardware infrastructure

# Network Slicing Application




| | UE | RAN | TN | Core network |
|---|---|---|---|---|
| Isolation Policy | ***URSP capability***<br>• Binding applications to S-NSSAIs based on rules | ***Isolation Policy***<br>• Carrier isolation;<br>• RB isolation;<br>• Together with transmission isolation (S-NSSAI to VLAN ID). | ***Isolation Policy***<br>• Flex-E transmission isolation based on VLAN ID; | ***Isolation Policy***<br>• AMF isolation;<br>• UPF isolation;<br>• Together with transmission isolation (S-NSSAI to VLAN ID). |



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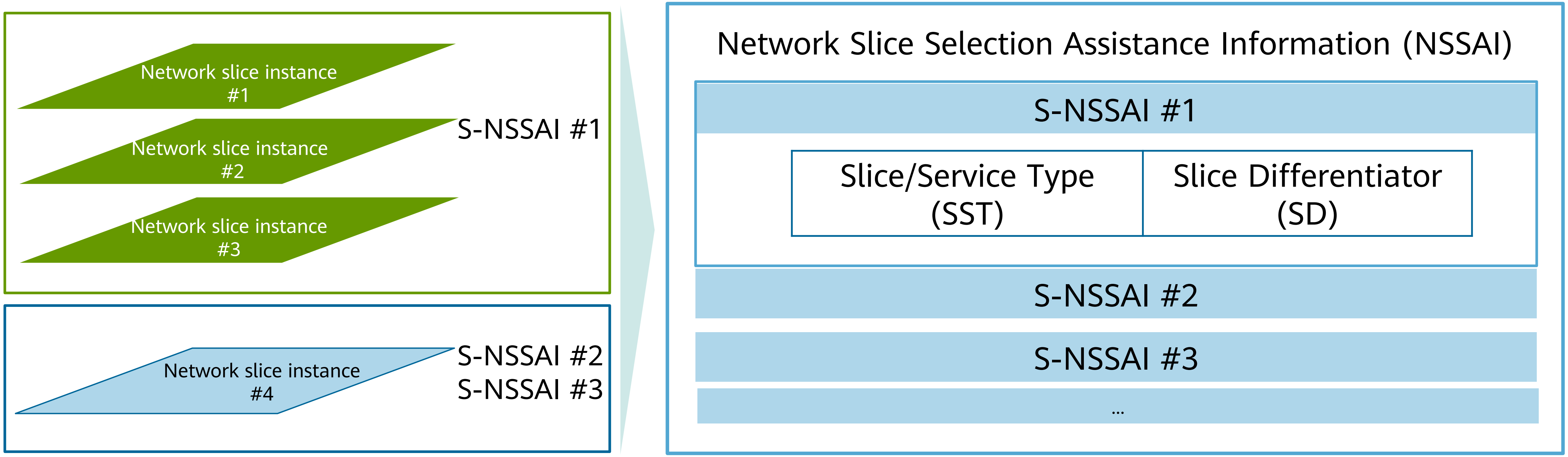
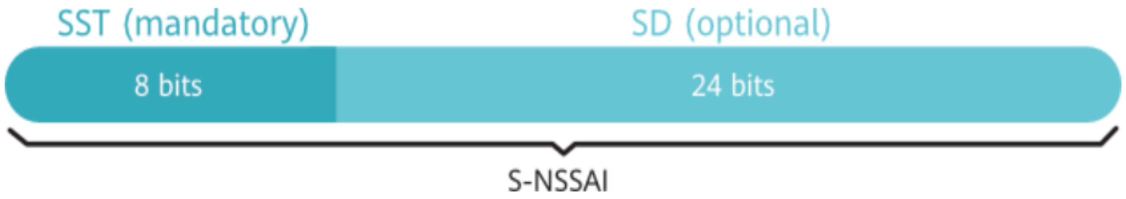
# Network Slice Types and Identifiers

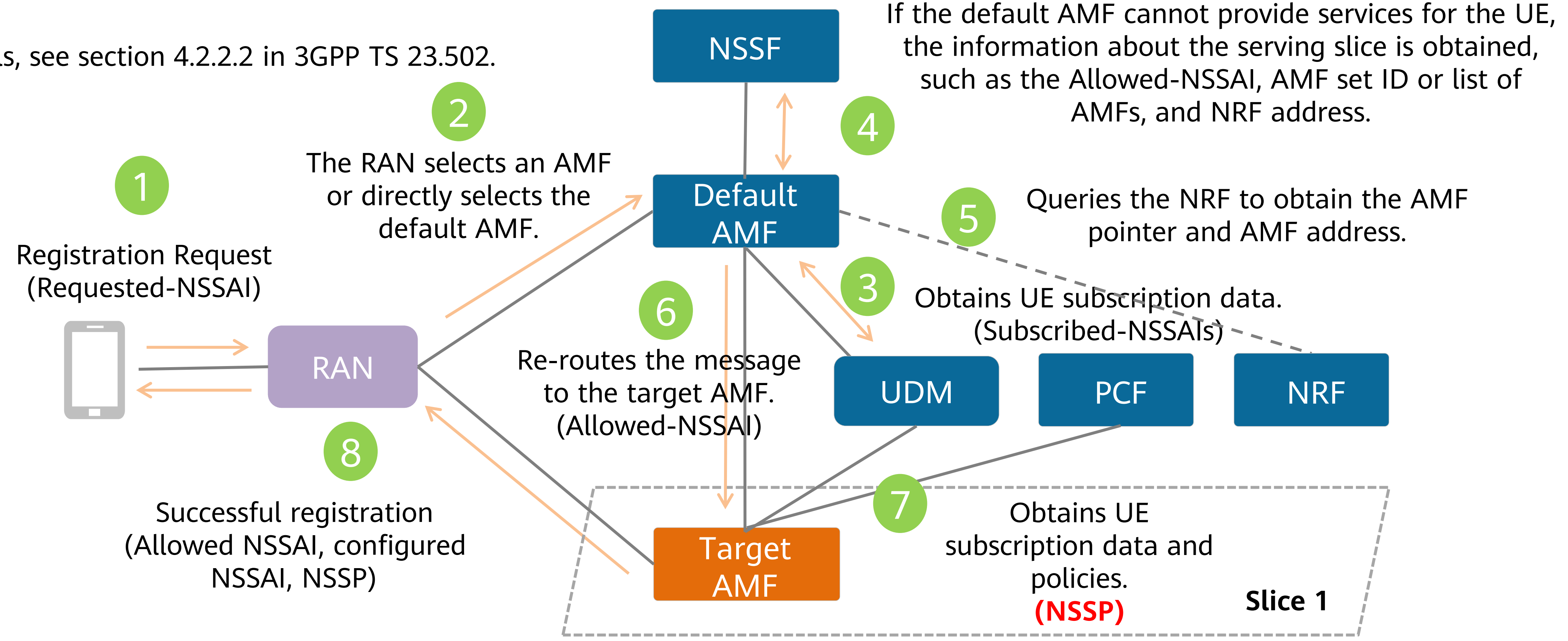



- An NSSAI is a set of one or more Single-NSSAIs (S-NSSAIs).
- Each S-NSSAI identifies a network slice. It consists of an SST and an SD
  - 3GPP defines some standard SST: eMBB(SST=1)/URLLC(SST=2)/MIoT(SST=3)/V2X(SST=4)

# Slice Selection Process: UE Registration and NSSAI-based Slice/AMF Selection

For details, see section 4.2.2.2 in 3GPP TS 23.502.

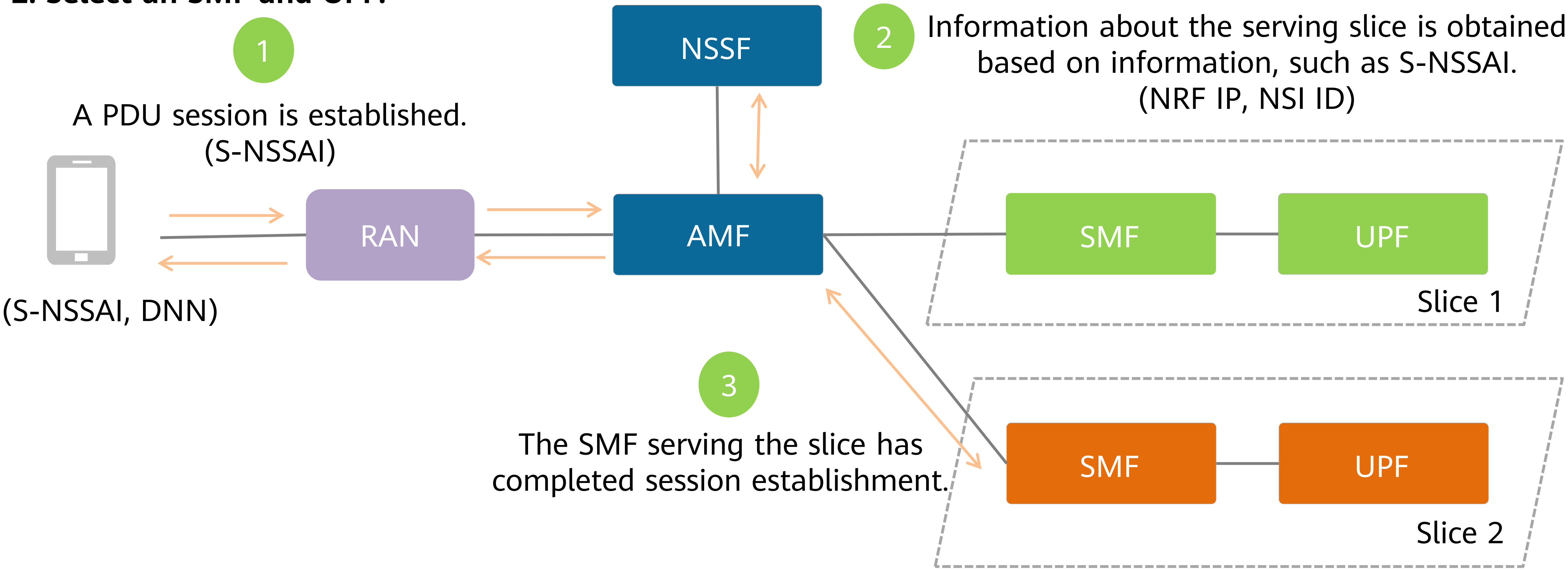



Note:

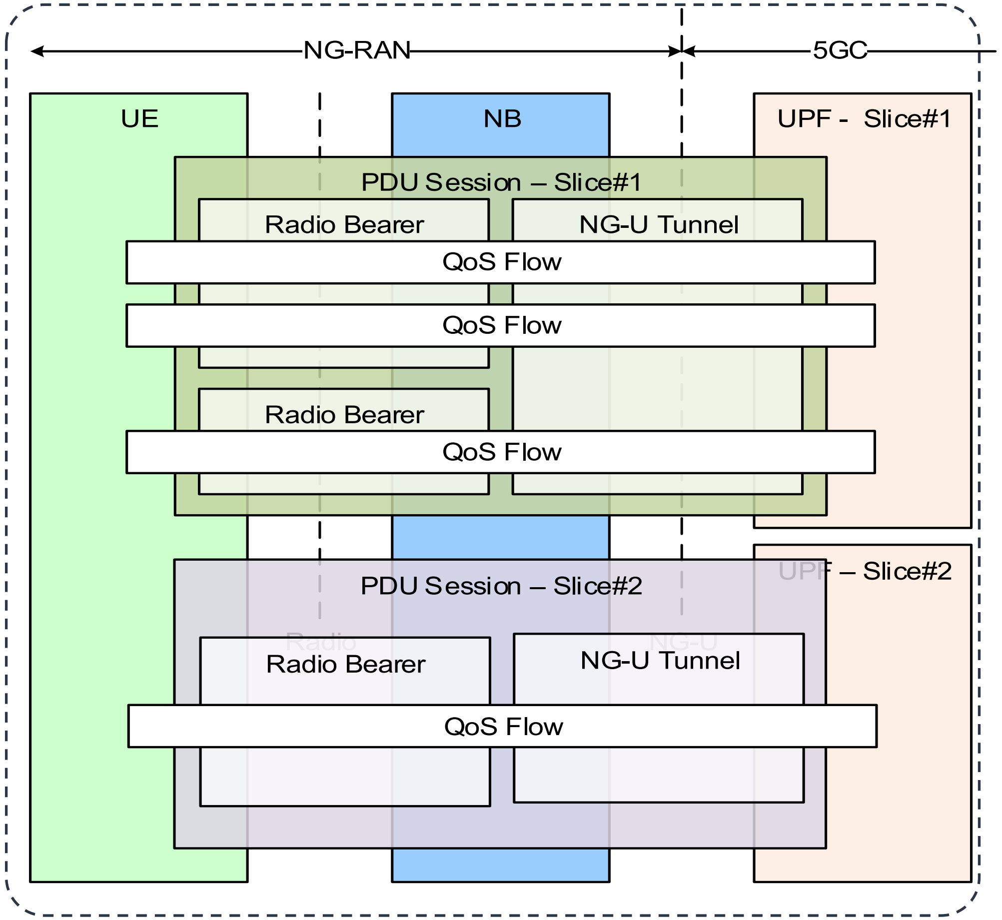
- An NSSP is used by a UE to associate app IDs with S-NSSAIs.

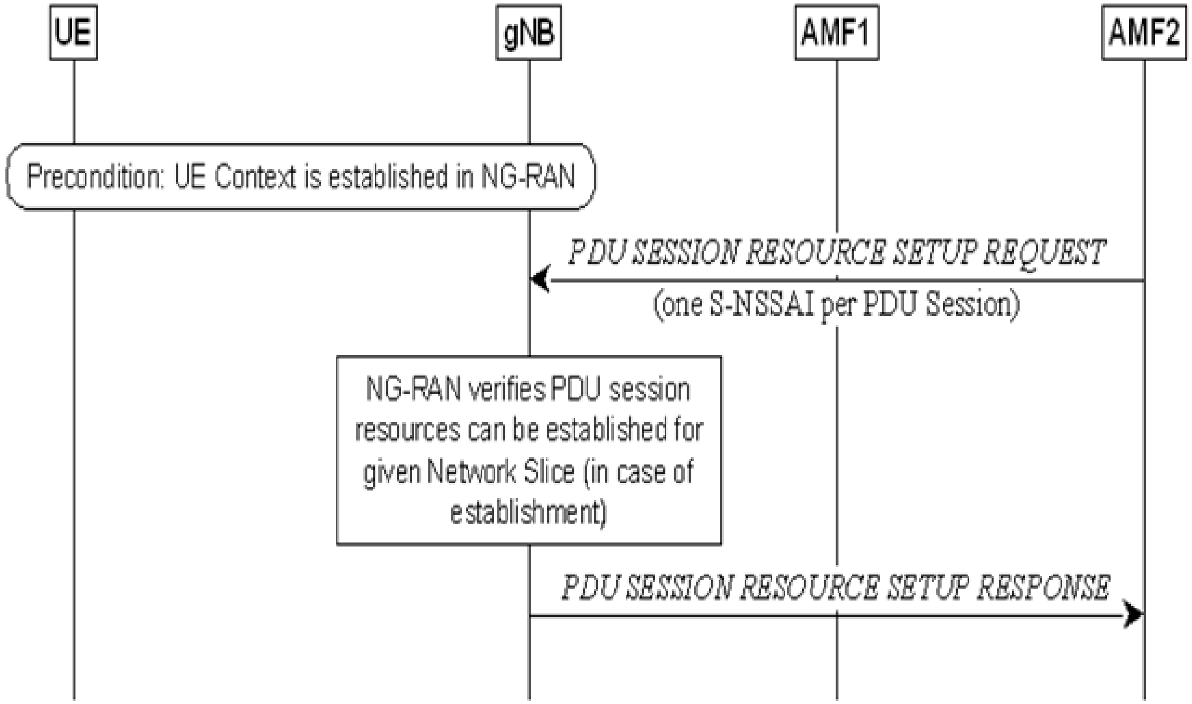
# Slice Selection Process: Session Establishment and SMF/UPF Selection Based on Slice Information Carried by the UE

- **Objectives:**
  - **1. Use a slice to establish a session (only one S-NSSAI is carried).**
  - **2. Select an SMF and UPF.**



# RAN Awareness for Network Slicing




- pDUSessionResourceSetupListSUReq
  - PDUSessionResourceSetupItemSUReq
    - pDUSessionID: ---- 0x5(5) ---- ***00000,00000101
    - pDUSessionNAS-PDU: ---- 0x00 ---- 00000001,00000000
    - s-NSSAI
      - sST: ---- 0x01 ---- 001*****
      - sD: ---- 0x010101 ---- 00000001,00000001,00000001



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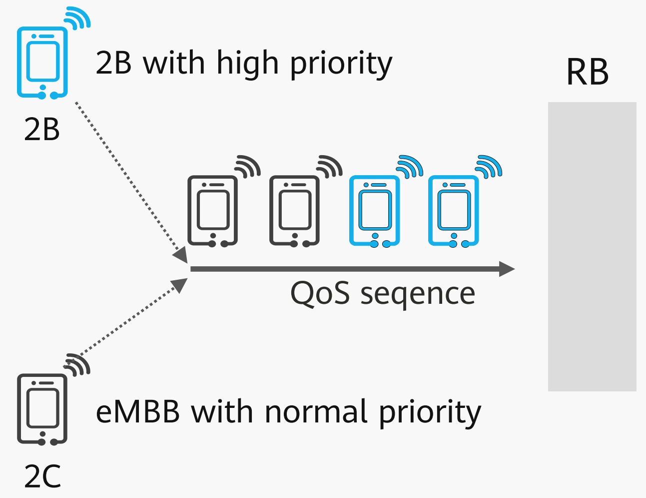
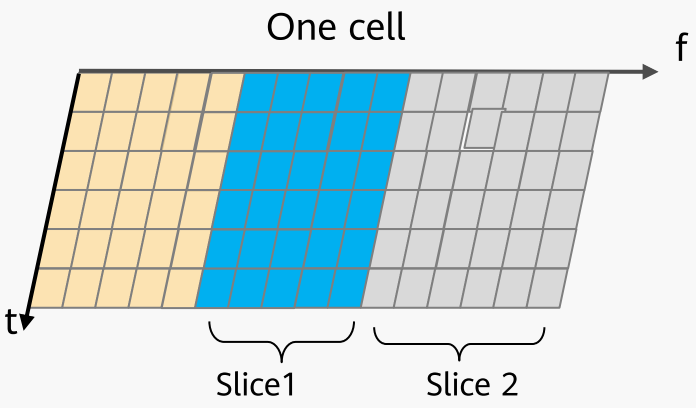
# RAN Resource Slicing Isolation Solutions

## QoS priority scheduling



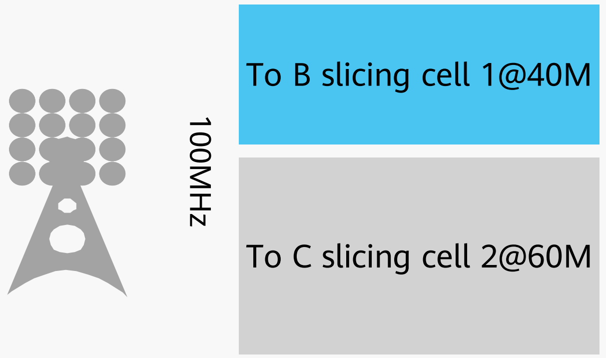

- 2B & 2C share one cell
- 2B user with high QoS priority will get more RB resources

## Resource reservation




- Slicing groups can be configured for different services, and RB can be reserved for each group
- Soft/Hard reservation
- QoS applied within slicing group

## Carrier separation




- Different cells serving different slicing groups (Hard reservation)
- QoS applied within each cell to further differentiate services

QoS → QoS + RB reservation / Carrier separation (Q0s and carrier separation do not need configuration
NRACellAlgoSwitch.NetworkslicingalgoSwitch=ENHANCED_NETWORKSLICE_SW for resource reservation



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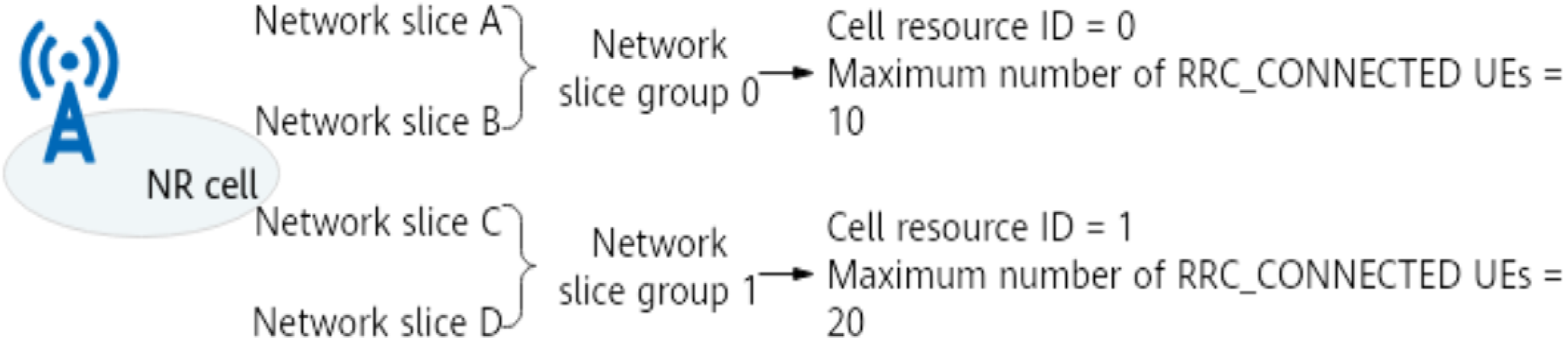
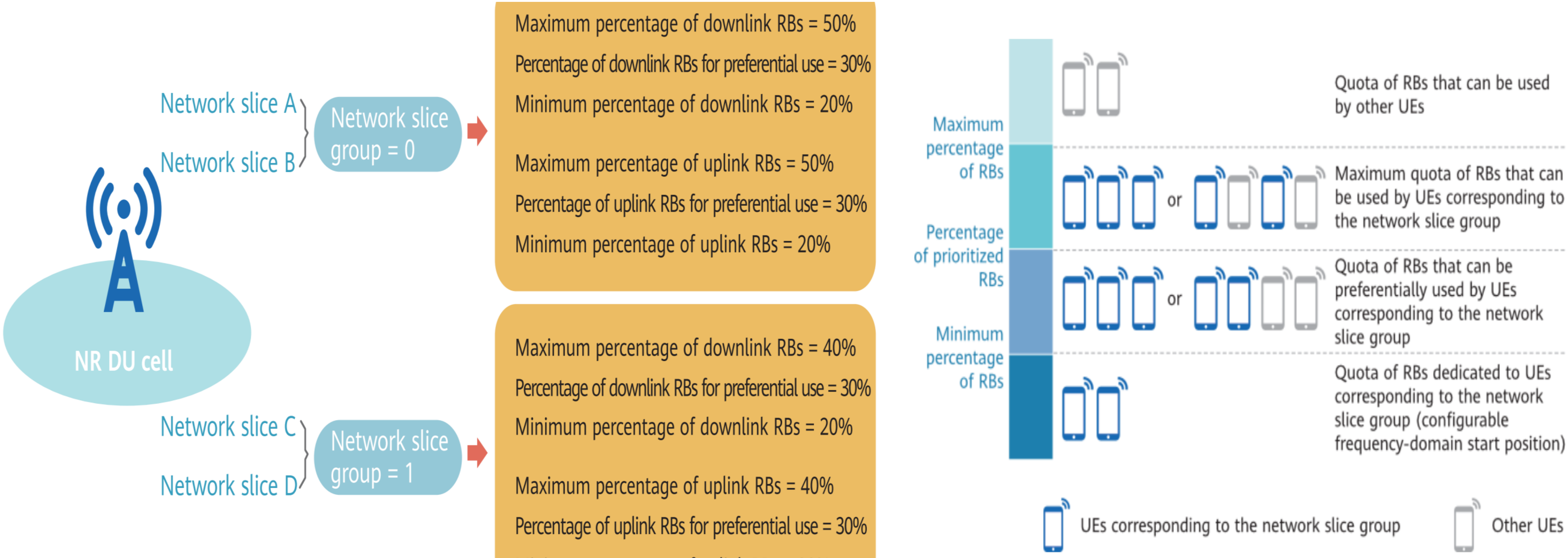
# Resource Reservation – RRC User Number




- The resource for a network slice is the number of RRC_CONNECTED UEs. Resources are managed by configuring NR cell resources, network slice groups, and slices in network slice groups
- It will be used for the slicing based admission control

# Resource Reservation – RB





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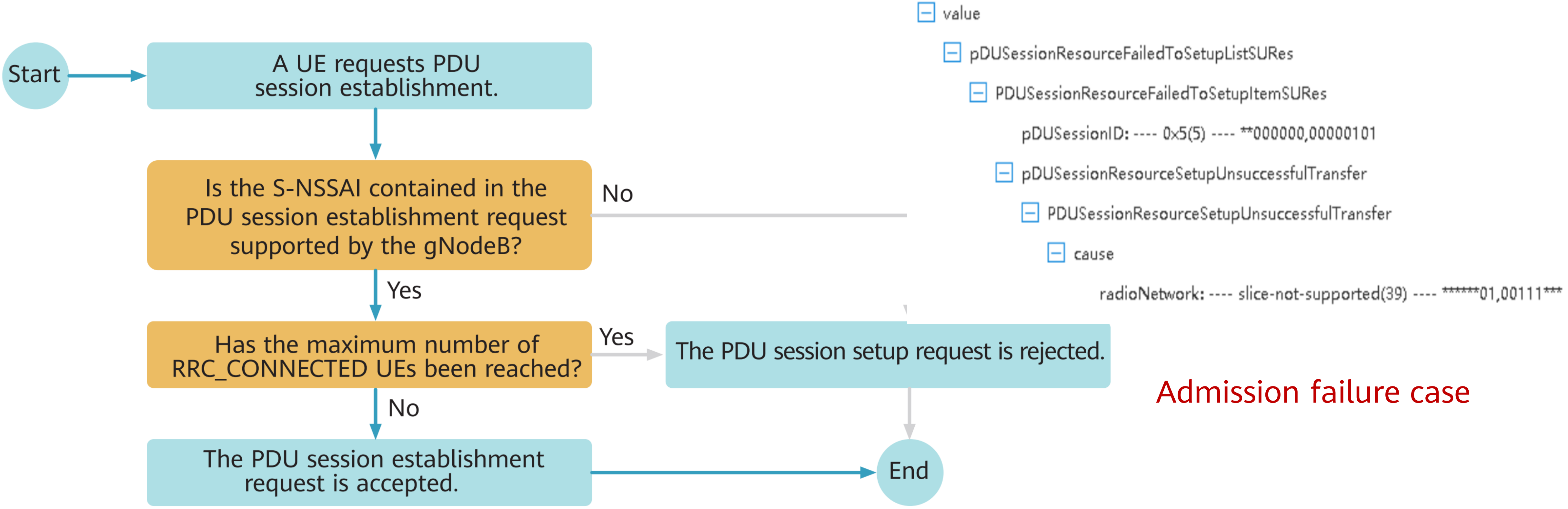
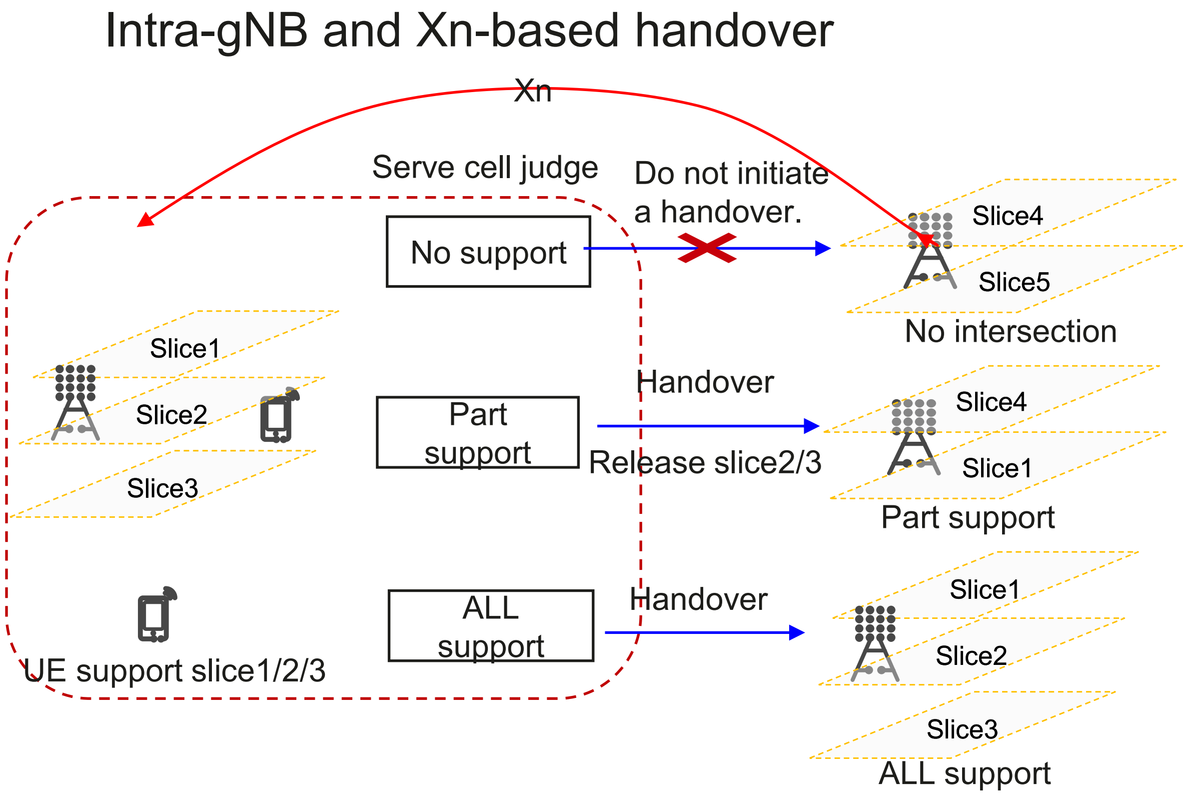
# RAN Admission Control for Slicing

- After network slices are deployed, the gNB performs admission control based on the network slices of UE and the number of RRC_CONNECTED UE allowed in the corresponding network slice group

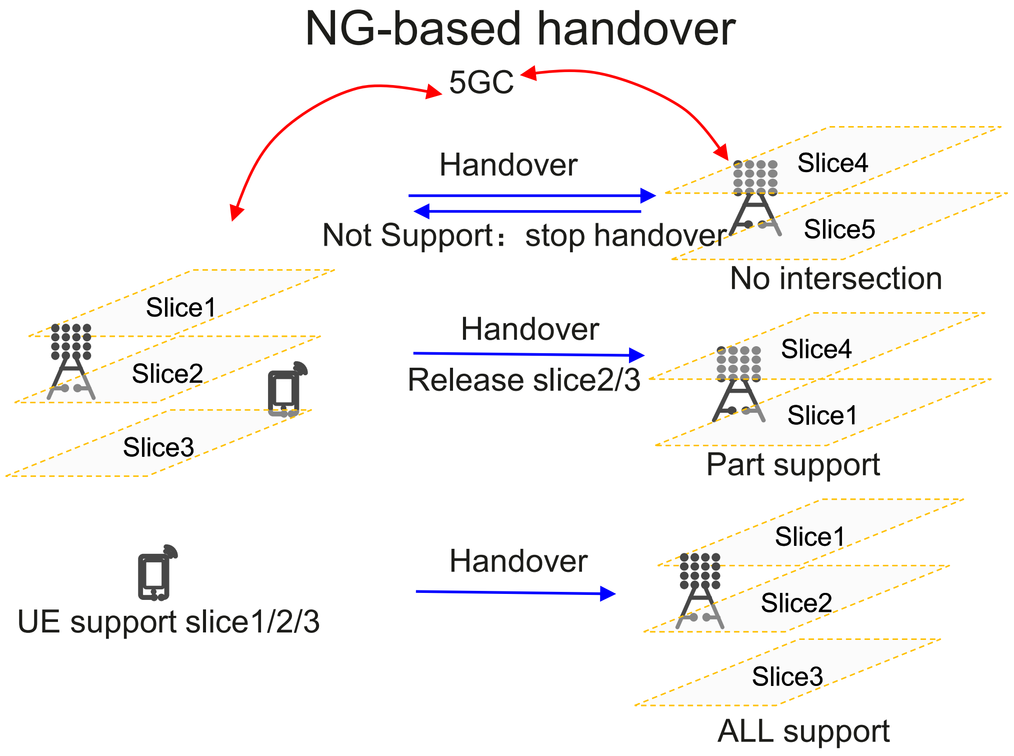



NRCellAlgoSwitch.*NetworkSliceAlgoSwitch=ADMISSION_BASED_ON_NS_ID_SW*

# RAN Admission Control for Slicing(*Cont.*)




The source cell can obtain slice configuration information of the target cell. Therefore, the source cell can determine whether to trigger handover to target cell.




As the source cell cannot obtain network slice configurations of a target cell, the source cell directly initiates a handover request to AMF. The target cell performs admission control based on network slices.





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# Contents

## 2. Optional Features







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# UE Power Saving

- **New technologies for UE power saving:**

Space Domain

  - **BWP Spatial Adaptation (Low-Frequency TDD)**
  - Reducing the Number of SCCs (Low-Frequency TDD)
  - Optimization for the Implementation of Switching from BWP1 to BWP2 (Low-Frequency TDD)
  - Exit from DRX and BWP2 of Weak-Coverage UEs (Low-Frequency TDD)
  - DCI Scheduling Optimization for Switching from BWP2 to BWP1 (Low-Frequency TDD)
  - QCI-Level Configuration for Power Saving BWP (Low-Frequency TDD)
  - Adaptation of the uplink smart preallocation duration
  - WUS

# BWP Spatial Adaptation

- The BWP spatial adaptation function complies with 3GPP Release 16. This function takes effect only for low-frequency UEs in SA networking.
- The mechanism of BWP spatial adaptation is as follows:
  - **For the downlink**
    - When this function is enabled, a UE that requires power saving reports the maximum number of downlink MIMO layers to be used to the base station, which then selects an appropriate power saving BWP for the UE.
    - The UE shuts down some receive antennas after switching to this BWP, and the base station performs downlink scheduling based on the UE-reported maximum number of downlink MIMO layers to reduce UE power consumption.

# BWP Spatial Adaptation (Cont.)

- The BWP spatial adaptation function complies with 3GPP Release 16. This function takes effect only for low-frequency UEs in SA networking.
- The mechanism of BWP spatial adaptation is as follows:
  - **For the uplink**
    - The number of RF chains can be controlled using the SRS configuration.
    - SRS resources are configured based on BWPs and therefore SRS resources can be dynamically adjusted through BWP switching.
    - The base station configures the 1T2R mode for power saving BWPs. In this way, after a UE switches from BWP1 to BWP2, it can reduce the number of transmit links.

# Network Analysis of BWP Spatial Adaptation

- Benefits
  - This function can reduce the power consumption of the UE communication module. The gains must be observed and evaluated on the UE side.
- Impacts
  - On the UE side: After this function is enabled, the throughput of UEs supporting BWP2 may **decrease** and the service delay of such UEs may **increase**.
  - On the base station side: BWP spatial adaptation depends on the power saving BWP function. When BWP spatial adaptation takes effect, some transmit and receive antennas of UEs in the power saving BWPs will be shut down. Therefore, the impact of power saving BWP on the network will be further aggravated.

# Dependency of BWP Spatial Adaptation

- Dependency
  - All NR-capable main control boards and NR TDD-capable baseband processing units support this function.
  - All NR-capable RF modules that work in low frequency bands support this function.
  - UEs must support the maxLayersMIMO-Adaptation-r16 capability defined in 3GPP Release 16.
- License requirements

| Feature ID | Feature Name | Model | Sales Unit |
|---|---|---|---|
| FOFD-030210 | UE Power Saving | NR0S00UEPS00 | per Cell |

# BWP Spatial Adaptation Deployment

- Activation
  - //Enabling BWP spatial adaptation, *this command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=BWP_MIMO_ADPT_SW-1;
- Deactivation
  - //Disabling BWP spatial adaptation, *this command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=BWP_MIMO_ADPT_SW-0;



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# BWP Spatial Adaptation Verification

- Activation verification
  - On the MAE-Access, choose Monitor > Signaling Trace > Signaling Trace Management, choose Uu Interface Trace.
  - On the displayed Uu Interface Trace page, check the RRC_RECFG message. Check whether the value of BWP-DownlinkDedicated > PDSCH-Config > maxMIMO-Layers-r16 for BWP2 changes. If it does, this function has taken effect.

# Q&A

1. Which of the following descriptions are correct about the BWP spatial adaptation function?

A. UE need to reports the maximum number of downlink MIMO layers to be used to the base station for power saving.

B. For the uplink, the base station configures the 1T2R mode for power saving BWPs.

C. UE shuts down some receive antennas after switching to the power saving BWP.

D. To reduce the number of SCCs for UEs to achieve UE power saving and overheating protection.

# UE Power Saving

- **New technologies for UE power saving:**
  - BWP Spatial Adaptation (Low-Frequency TDD)
  - **Reducing the Number of SCCs (Low-Frequency TDD)**
  - Optimization for the Implementation of Switching from BWP1 to BWP2 (Low-Frequency TDD)
  - Exit from DRX and BWP2 of Weak-Coverage UEs (Low-Frequency TDD)
  - DCI Scheduling Optimization for Switching from BWP2 to BWP1 (Low-Frequency TDD)
  - QCI-Level Configuration for Power Saving BWP (Low-Frequency TDD)
  - Adaptation of the uplink smart preallocation duration
  - WUS

Frequency Domain

# Reducing the Number of SCCs (Low-Frequency TDD)

- Reducing the number of SCCs of the UE, the power consumption of UE's communication modules can be reduced.
  - This function uses standard protocol-compliant procedures to reduce the number of SCCs for UEs to achieve UE power saving and overheating protection. This function applies only to low-frequency UEs in SA networking.

Overheating Protection


UE Power Saving



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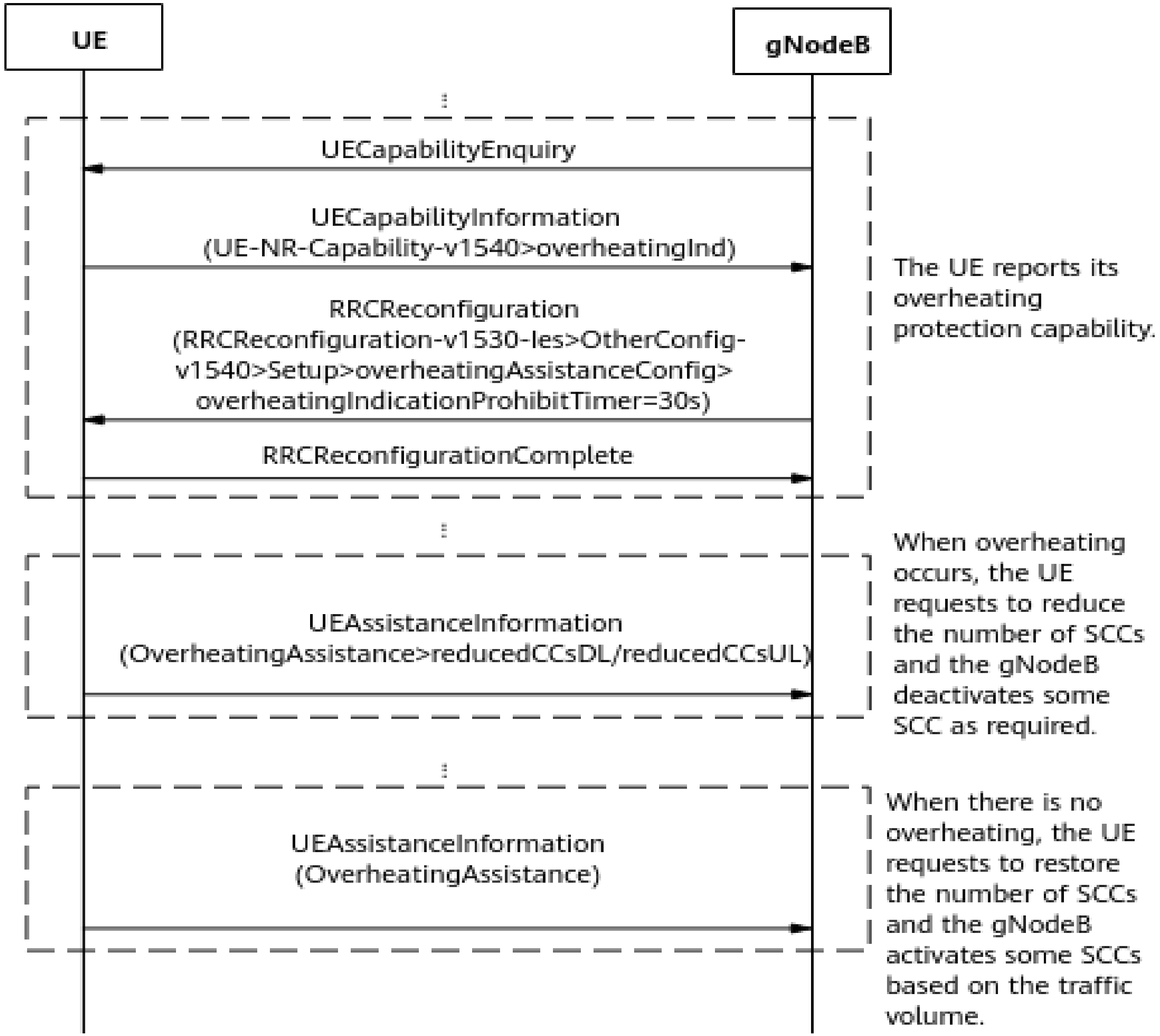
# Process of Reducing the Number of SCCs for UE Overheating Protection

- The UE reports its overheating protection capability.
- When overheating occurs, the UE requests to reduce the number of SCCs.
- When there is no overheating, the UE requests to restore the number of SCCs.

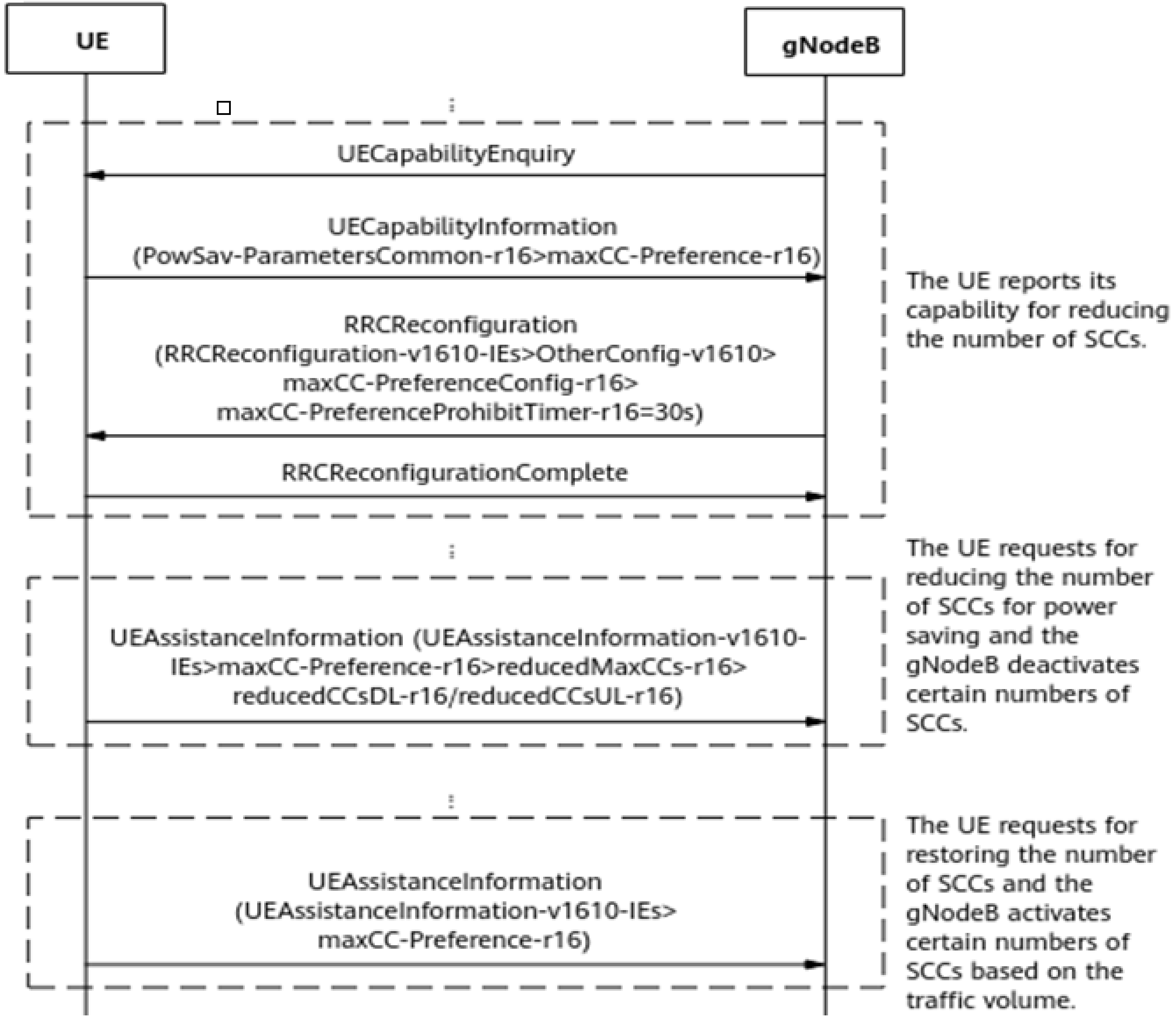



The number of activated SCCs allowed in the uplink does not exceed the number of activated SCCs allowed in the downlink.

# Process of Reducing the Number of SCCs for UE Power Saving

- The UE reports its 3GPP Release 16-compliant capability for reducing the number of SCCs.
- The UE proactively requests for SCC reduction for power saving.
- When power saving is no longer required, the UE can initiate SCC restoration.

The number of activated SCCs allowed in the uplink does not exceed the number of activated SCCs allowed in the downlink.



# Enable the Function of the Reducing the Number of SCCs

- For UEs with different capabilities, different parameters are used to control the function of reducing the number of SCCs.

| UE Capabilities | Function Switch |
|---|---|
| Support only the **overheatingInd** capability defined in 3GPP Release 15. | This function is controlled by the **OVERHEATING_ASSISTANCE_INFO_SW** and **UE_SCC_DEACTIVATE_SW** options of the **NRCellAlgoSwitch.UeAssistanceInfoSwitch** parameter. |
| Support only the **maxCC-Preference-r16** capability defined in 3GPP Release 16. | This function is controlled by the **UE_SCC_DEACTIVATE_SW** option of the **NRCellAlgoSwitch.UeAssistanceInfoSwitch** parameter. |

# Network Analysis of Reducing the Number of SCCs

- Benefits
  - the power consumption of UEs' communication modules can be reduced.
  - The specific reduction in power consumption is related to the number of reduced SCCs. The power reduction is also related to the chip of UEs.
- Impacts
  - On the UE side: The base station reduces the number of SCCs allowed to be activated for the UE. As a result, the UE-perceived service rate decreases along with the UE power saving.
  - On the base station side: The average uplink/downlink cell throughput and the average uplink/downlink UE throughput may decrease.

# Dependency of Reducing the Number of SCCs

- Dependency
  - All NR-capable main control boards and NR TDD-capable baseband processing units support this function.
  - All NR-capable RF modules that work in low frequency bands support this function.
  - UEs must support the **overheatingInd** capability defined in 3GPP Release 15 or **the maxCC-Preference-r16** capability defined in 3GPP Release 16.
  - No license requirements for this function.

# Reducing the Number of SCCs Deployment

- Activation
  - //Turning on the switch for UE SCC deactivation, *this command is a high-risk command.*
  - MOD NRCELLALGOSWITCH: NrCellId=1, UeAssistanceInfoSwitch=UE_SCC_DEACTIVATE_SW-1;
  - //Turning on the overheating assistance information processing switch, *this command is a high-risk command.*
  - MOD NRCELLALGOSWITCH: NrCellId=1, UeAssistanceInfoSwitch=OVERHEATING_ASSISTANCE_INFO_SW-1;
- Deactivation
  - //Turning off the switch for UE SCC deactivation and the overheating assistance information processing switch, *this command is a high-risk command.*
  - MOD NRCELLALGOSWITCH: NrCellId=1, UeAssistanceInfoSwitch= OVERHEATING_ASSISTANCE_INFO_SW-0&UE_SCC_DEACTIVATE_SW-0;



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# Reducing the Number of SCCs Verification

- Activation verification
  - On the MAE-Access, choose Monitor > Signaling Trace > Signaling Trace Management, choose Uu Interface Trace.
  - On the displayed Uu Interface Trace page, check the RRC_RECFG message. If overheatingAssistanceConfig>overheatingIndicationProhibitTimer or maxCC-PreferenceConfig-r16>maxCC-PreferenceProhibitTimer-r16 exists in the message, this function has taken effect.





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# UE Power Saving

- **New technologies for UE power saving:**
  - BWP Spatial Adaptation (Low-Frequency TDD)
  - Reducing the Number of SCCs (Low-Frequency TDD)
  - **Optimization for the Implementation of Switching from BWP1 to BWP2 (Low-Frequency TDD)**
  - **Exit from DRX and BWP2 of Weak-Coverage UEs (Low-Frequency TDD)**
  - **DCI Scheduling Optimization for Switching from BWP2 to BWP1 (Low-Frequency TDD)**
  - **QCI-Level Configuration for Power Saving BWP (Low-Frequency TDD)**
  - Adaptation of the uplink smart preallocation duration
  - WUS

Frequency Domain





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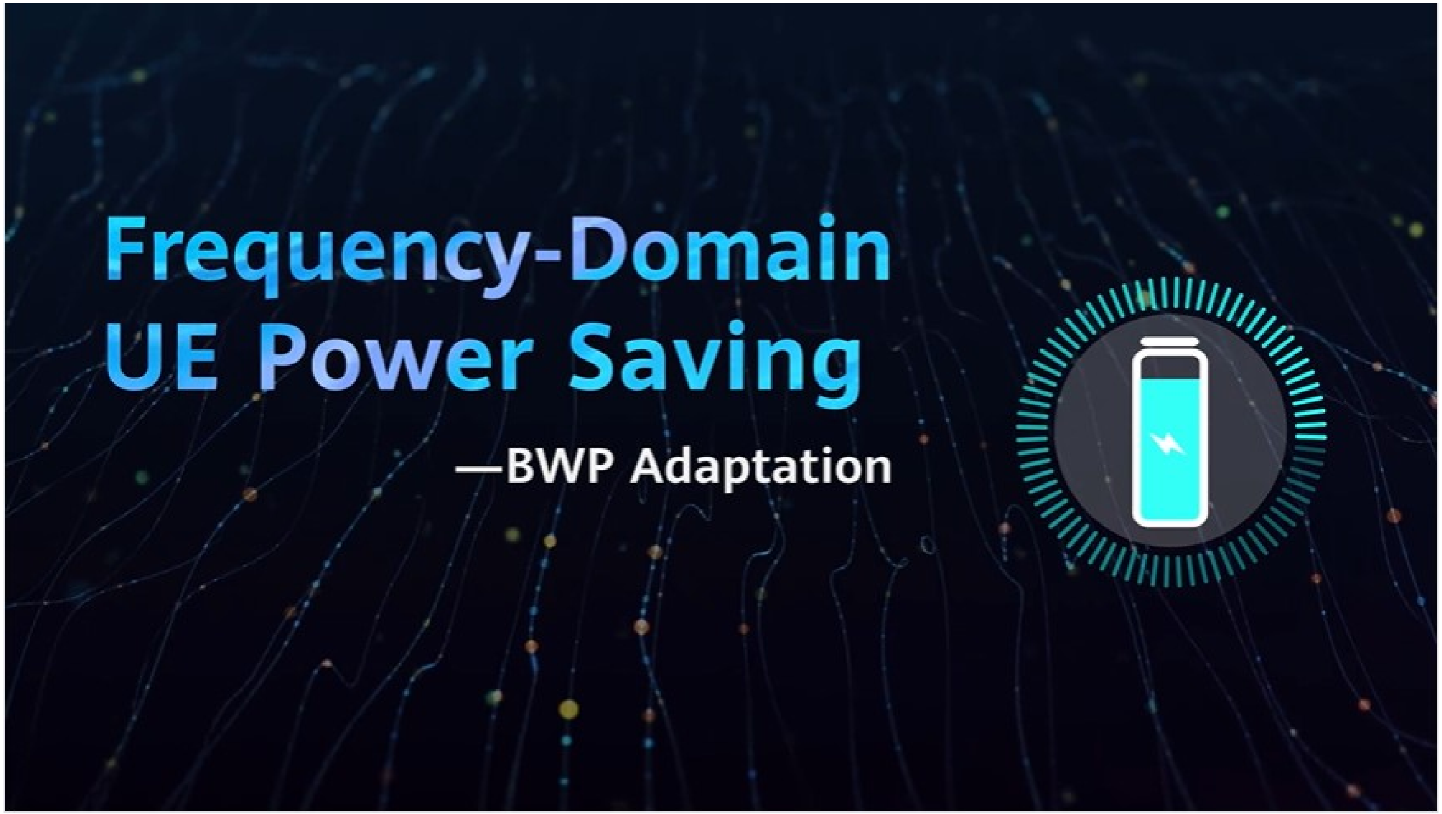
# BWP Switching

- When certain conditions are met, a base station and a UE can switch from one dedicated BWP to the other at the same time. This process is known as BWP switching.



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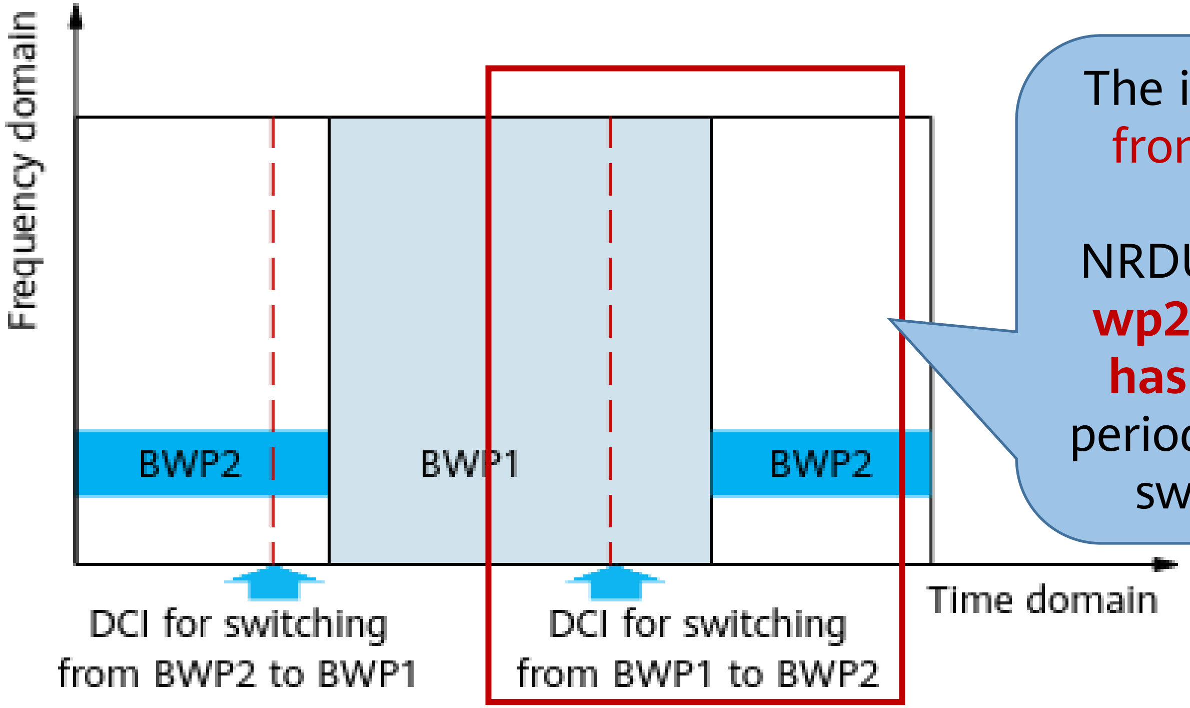
# Optimization for the Implementation of Switching from BWP1 to BWP2

- When certain conditions are met, a base station and a UE can switch from one dedicated BWP to the other at the same time. This process is known as BWP switching.
- Currently, downlink control information (DCI) is used to inform a UE of switching between dedicated BWPs.




The implementation of switching from BWP1 to BWP2 has been optimized, and the NRDUCellUePwrSaving.**Bwp1ToBwp2EvaluatePeriod parameter has been added** to specify the period for determining whether to switch from BWP1 to BWP2.

# Switching from BWP1 to BWP2 Conditions

- The base station periodically determines whether a UE meets the conditions for switching from BWP1 to BWP2. The period is specified by **NRDUCellUePwrSaving.Bwp1ToBwp2EvaluatePeriod**.
- The base station and a UE switch from BWP1 to BWP2 when all of the following conditions are met:
  - The downlink RLC throughput of a UE is lower than both the threshold specified by NRDUCellUePwrSaving.Bwp1ToBwp2DlThptThld and the downlink throughput calculated based on radio channel quality.
  - The uplink RLC throughput of a UE is lower than both the threshold specified by NRDUCellUePwrSaving.Bwp1ToBwp2UlThptThld and the uplink throughput calculated based on radio channel quality.



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# Exit from DRX and BWP2 of Weak-Coverage UEs

- After DRX and power saving BWP are enabled, the DRX timer status (active time or sleep time) or BWP status (full-bandwidth BWP1 or narrow-bandwidth BWP2) of weak-coverage UEs is more likely to be inconsistent with that on the base station side. This increases the service drop rate.
- To prevent this, exit from DRX and BWP2 of weak-coverage UEs are introduced. This function is controlled by the **WEAK_COV_DRX_BWP2_EXIT_SW** option of the **NRDUCellUePwrSaving.BwpPwrSavingSw** parameter.

# The mechanism of Exit from DRX and BWP2 of Weak-Coverage UEs

Enable this function

- UE initially accesses a cell
  - Msg3-based DMRS RSRP is smaller than the threshold.
  - OR
  - Msg3-based DMRS SINR is smaller than the threshold.
- DRX parameters or BWP2 resource information is configured
  - The CQI measurement result periodically reported by a UE is smaller than the threshold.
  - OR
  - The uplink SINR is smaller than the threshold.

Identify a weak-coverage UE in UE power saving scenarios.

- DRX parameters or BWP2 resource information will not be included in the RRC reconfiguration message for the UE.
- UEs in the corresponding cell will switch from BWP2 to BWP1 or exit DRX mode.

# DCI Scheduling Optimization for Switching from BWP2 to BWP1

- CCE resources on BWP2 are limited. To reduce the probability of failed DCI scheduling for switching from BWP2 to BWP1 and reduce the service drop rate, DCI scheduling optimization for switching from BWP2 to BWP1 is introduced.
- This function is controlled by the **BWP2_SWITCHING_DCI_SCH_OPT_SW** option of then **NRDUCellUePwrSaving.BwpPwrSavingSw** parameter and is disabled by default.

# QCI-Level Configuration for Power Saving BWP

- The BWP2 switch for UE power saving is a cell-level parameter. Therefore, the power saving BWP function cannot be disabled separately for ToB services on the wide area network (WAN).
- To avoid delay issues of ToB UEs running low-latency services, QCI-level configuration for power saving BWP is introduced.
- This function is controlled by the **NRDUCellQciBearer.QciBwp2Ind** parameter whose default value is NOT_CONFIG.
  - When the **BWP2_SWITCH** option of the **NRDUCellUePwrSaving.BwpPwrSavingSw** parameter is selected and the **NRDUCellQciBearer.QciBwp2Ind** parameter is set to **NOT_SUPPORT**, power saving BWP can be disabled separately for ToB services.

# Network Analysis for BWP Switching Related Optimization

- Impacts
  - After DCI scheduling optimization for switching from BWP2 to BWP1 is enabled, the service drop rate may decrease.
  - After exit from DRX and BWP2 of weak-coverage UEs is enabled, the service drop rate may decrease.
  - After QCI-based configuration for power saving BWP takes effect for ToB services, the service delay is shortened and the average uplink and downlink UE throughput increases.

# Dependency of BWP Switching Related Optimization

- Dependency
  - All NR-capable main control boards and NR TDD-capable baseband processing units support this function.
  - All NR-capable RF modules that work in low frequency bands support this function.
  - UEs must support multiple (two or more) dedicated BWPs.
  - The license depends on the “UE power saving” license.



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# BWP Switching Related Optimization Function Deployment

- Activation
  - //Configuring the BWP1 to BWP2 evaluation period. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, Bwp1ToBwp2EvaluatePeriod=10;
  - //Turning on the switch for DCI scheduling optimization for switching from BWP2 to BWP1 as recommended. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=BWP2_SWITCHING_DCI_SCH_OPT_SW-1;
  - //(Optional) Performing the following operations if enabling exit from DRX and BWP2 of weak-coverage UEs is required. *This command is a high-risk command.*
  - //Turning on the switch for exit from DRX and BWP2 of weak-coverage UEs
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=WEAK_COV_DRX_BWP2_EXIT_SW-1;

# BWP Switching Related Optimization Function Deployment (Cont.)

- Activation
  - //Configuring the initial DMRS RSRP weak coverage threshold and initial DMRS SINR weak coverage threshold. *This command is a high-risk command.*
  - MOD NRDUCELLDMRS: NrDuCellId=1, InitDmrsRsrpWeakCovThld=-130, InitDmrsSinrWeakCovThld=0;
  - //Configuring the weak coverage threshold offset, weak coverage CQI threshold, and weak coverage uplink SINR threshold. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, WeakCoverageThldOffset=5, WeakCoverageCqiThld=5, WeakCoverageUlSinrThld=5;
  - //(Optional) Setting the NRDUCellQciBearer.QciBwp2Ind parameter to NOT_SUPPORT for a QCI (QCI 82 is used as an example) so that power saving BWP can be disabled separately for ToB services.
  - MOD NRDUCELLQCIBEARER: NrDuCellId=1, Qci=82, QciBwp2Ind=NOT_SUPPORT;

# BWP Switching Related Optimization Function Deployment (Cont.)

- Deactivation
  - //Turning off the BWP switching optimization switch. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=BWP_SWITCHING_OPT_SW-0;
  - //Turning off the switch for DCI scheduling optimization for switching from BWP2 to BWP1. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=BWP2_SWITCHING_DCI_SCH_OPT_SW-0;
  - //Turning off the switch for exit from DRX and BWP2 of weak-coverage UEs. *This command is a high-risk command.*
  - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, BwpPwrSavingSw=WEAK_COV_DRX_BWP2_EXIT_SW-0;

# Q&A

1. Which of the following description is correct?

   A. If the uplink&downlink RLC throughput of a UE is lower than the uplink&downlink throughput calculated based on radio channel quality, then switching from BWP1 to BWP2.

   B. For weak-coverage terminal, the exit from DRX and BWP2 function is controlled by the WEAK_COV_DRX_BWP2_EXIT_SW to decreases the service drop rate.

   C. The CQI and uplink SINR are used for initial access UEs to identify the UE status in the function of exit from DRX and BWP2.

   D. To avoid delay issues of ToB UEs running low-latency services, Cell-level configuration for power saving BWP is introduced.



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# UE Power Saving

- **New technologies for UE power saving:**
  - BWP Spatial Adaptation (Low-Frequency TDD)
  - Reducing the Number of SCCs (Low-Frequency TDD)
  - Optimization for the Implementation of Switching from BWP1 to BWP2 (Low-Frequency TDD)
  - Exit from DRX and BWP2 of Weak-Coverage UEs (Low-Frequency TDD)
  - DCI Scheduling Optimization for Switching from BWP2 to BWP1 (Low-Frequency TDD)
  - QCI-Level Configuration for Power Saving BWP (Low-Frequency TDD)
  - **Adaptation of the uplink smart preallocation duration**
  - WUS

Time Domain

# Adaptation of the Uplink Smart Preallocation Duration Overview

- Optimized smart preallocation:
  - Smart preallocation is triggered only when there is valid downlink scheduling data (excluding MAC CEs and padding data).
  - This reduces the frequency of triggering smart preallocation to reduce UE power consumption.

# Adaptation of the Uplink Smart Preallocation Duration Network Analysis

- Benefits
  - After adaptation of the uplink smart preallocation duration is enabled, UEs consume less power and the average number of PRBs used by UEs in uplink preallocation reduces.
- Impacts
  - This function may have the following impact in light- or medium-load scenarios:
    - The average number of PRBs used by UEs in uplink preallocation and the uplink PRB usage decrease.
    - Uplink interference to neighboring cells decreases.



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# Adaptation of the Uplink Smart Preallocation Duration Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>None<br>• RF Modules<br>None |
| **Software Requirements** | • Prerequisite Functions<br>Uplink smart preallocation<br>• Mutually Exclusive Functions<br>None |
| **Network Requirements** | None |
| **NE Requirements** | None |

- Licenses: None



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# Adaptation of the Uplink Smart Preallocation Duration Deployment (Cont.)

- Activation
  - //Enabling adaptation of the uplink smart preallocation duration. *This command is a high-risk command.*
    - MOD NRDUCELLPUSCH: NrDuCellId=0, UlPreallocationSwitch=UL_SMART_PREALLOCATION_OPT_SW-1;
- Deactivation
  - //Disabling adaptation of the uplink smart preallocation duration. *This command is a high-risk command.*
    - MOD NRDUCELLPUSCH: NrDuCellId=0, UlPreallocationSwitch=UL_SMART_PREALLOCATION_OPT_SW-1;



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# Adaptation of the Uplink Smart Preallocation Duration Verification

- Activation verification
  - If the average number of PRBs used by UEs in uplink preallocation (indicated by N.PRB.UL.Prealloc.Used.Avg) decreases after adaptation of the function is enabled, this function has taken effect.
- Network monitoring
  - Observe the following counters

| Counter ID | Counter Name |
|---|---|
| 1911825115 | N.PRB.UL.Prealloc.Used.Avg |
| 1911816696 | N.ThpVol.UL.Cell |

# UE Power Saving

- **New technologies for UE power saving:**
  - BWP Spatial Adaptation (Low-Frequency TDD)
  - Reducing the Number of SCCs (Low-Frequency TDD)
  - Optimization for the Implementation of Switching from BWP1 to BWP2 (Low-Frequency TDD)
  - Exit from DRX and BWP2 of Weak-Coverage UEs (Low-Frequency TDD)
  - DCI Scheduling Optimization for Switching from BWP2 to BWP1 (Low-Frequency TDD)
  - QCI-Level Configuration for Power Saving BWP (Low-Frequency TDD)
  - Adaptation of the uplink smart preallocation duration
  - **WUS**

Time Domain





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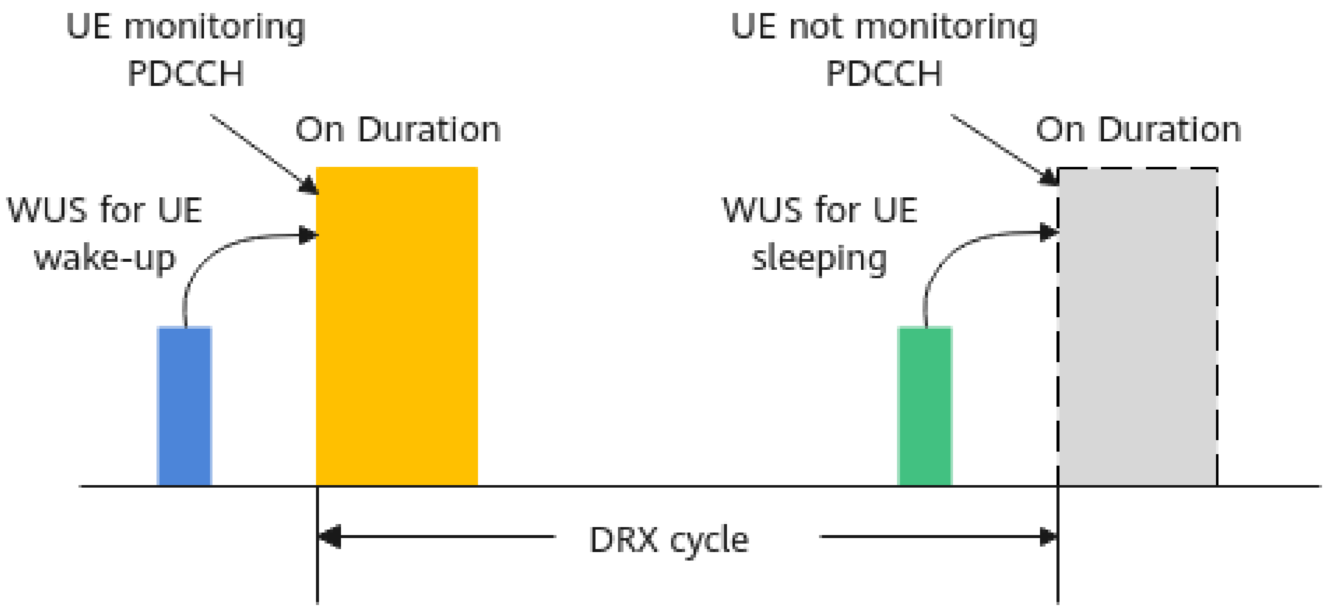
# WUS Overview

- Wakeup signals are used to instruct a UE whether it needs to wake up in the On Duration of the next long DRX cycle to monitor PDCCH. This function can be used only for low-frequency UEs in SA networking.



# WUS Overview (Cont.)

- The process of this function is as follows:
  1. The UE and base station exchange capability information.
  2. The gNodeB delivers the DCI format 2_6 configuration.
  3. DCI format 2_6 is used to indicate whether a UE needs to wake up or can remain sleeping.
- Parameter:
  - This function is controlled by the **DRX_ADAPTATION_SW** option of the **NRDUCellUePwrSaving**.***NrDuCellDrxAlgoSwitch*** parameter.
  - The setting of this option takes effect only for UEs that newly access or are newly handed over to the cell.

# WUS Network Analysis

- Benefits
  - This function reduces power consumption of the UE communication module.
- Impacts
  - After the WUS function is enabled, the following may occur:
    - Decrease in average uplink and downlink cell throughput; Significant decrease in average uplink and downlink UE throughput
    - Increase in delay
    - Possible increase or decrease in the uplink and downlink IBLERs or RBLERs
    - Increase in the service drop rate

# WUS Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>None<br>• RF Modules<br>None |
| **Software Requirements** | • Prerequisite Functions<br>DRX<br>• Mutually Exclusive Functions<br>None |
| **Network Requirements** | None |
| **NE Requirements** | UEs must support long DRX cycles and the **drx-Adaptation-r16** capability defined in 3GPP Release 16. |

# WUS Deployment (Cont.)

- Licenses
  - Feature licenses:

| Feature ID | RAT | Feature Name | Model | NE | Sales Unit |
|---|---|---|---|---|---|
| FOFD-030210 | NR TDD | UE Power Saving | NR0S00UEPS00 | gNodeB | per Cell |

# WUS Deployment (Cont.)

- Activation
  - //Enabling the WUS function. *This command is a high-risk command.*
    - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, NrDuCellDrxAlgoSwitch=DRX_ADAPTATION_SW-1;
- Deactivation
  - //Disabling the WUS function. *This command is a high-risk command.*
    - MOD NRDUCELLUEPWRSAVING: NrDuCellId=1, NrDuCellDrxAlgoSwitch=DRX_ADAPTATION_SW-0;



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# WUS Verification

- Activation verification
  - Enable a UE that supports WUS to initially access the network.
  - Choose **Uu Interface Trace.**
  - Check the RRC_RECFG message.
    - If the message contains **PhysicalCellGroupConfig->dcp-Config-r16**, the WUS function has taken effect.
- Network monitoring
  - Average uplink and downlink cell throughput, average uplink and downlink UE throughput, delay, uplink and downlink IBLERs and RBLERs

| Counter ID | Counter Name |
|---|---|
| 1911820769 | N.Cdrx.Sleep.Dur.Total |
| 1911820770 | N.Cdrx.Active.Dur.Total |



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# Q&A

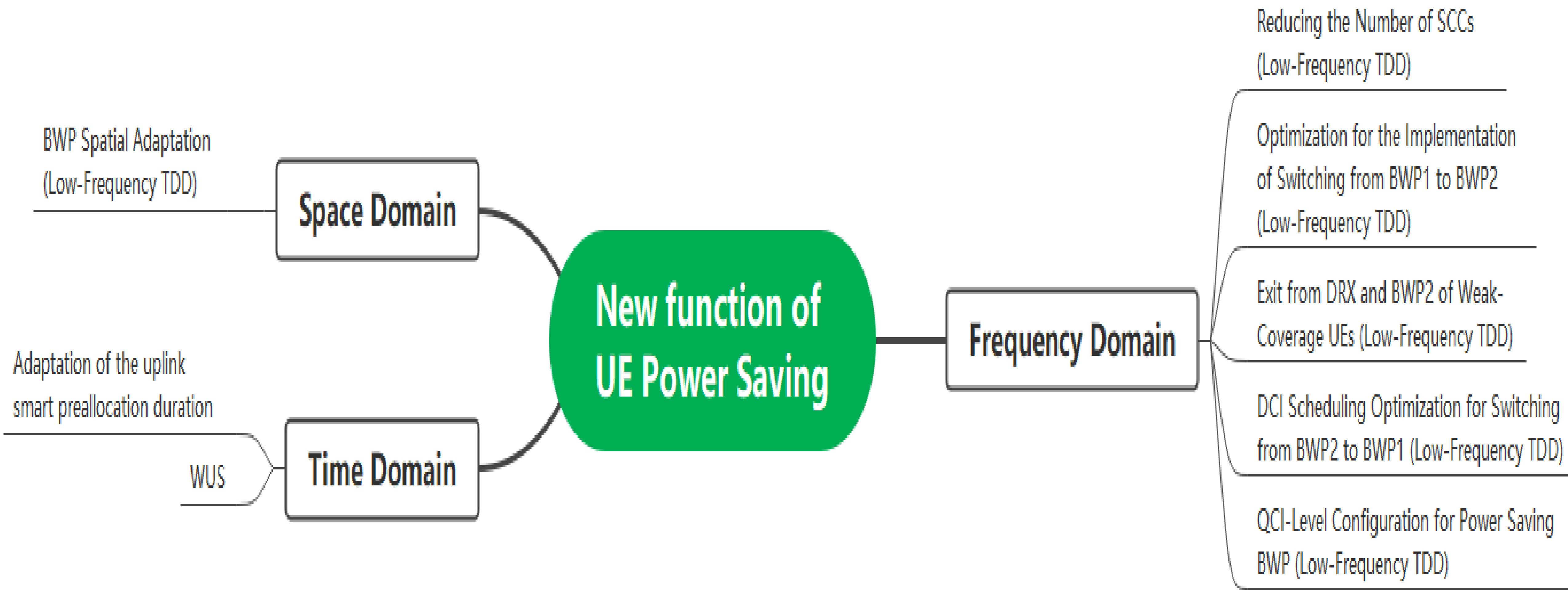
1. Which of the following descriptions of the WUS function are correct? (    )

   A. This function applies only to low-frequency UEs in SA networking.

   B. Wakeup signals are used to instruct a UE whether it needs to wake up in the On Duration of the next long DRX cycle to monitor PDCCH.

   C. The WUS function depends on the DRX function.

# Section Summary



# Contents

## 2. Optional Features

# VoNR

- **New technologies for VoNR:**
  - **Increase in the Maximum Number of RLC AM Retransmissions**
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions

# Increase in the Maximum Number of RLC AM Retransmissions

- When the voice service drop rate is high, this function increases the maximum number of ARQ retransmissions in RLC AM for VoNR UEs based on the setting of the **gNBRlcParamGroup.gNBMaxVonrAmRetransNum** parameter, thereby reducing the service drop rate.
- After this function is enabled, the maximum number of ARQ retransmissions in RLC AM is changed from 32 (fixed before this function is enabled) to a configurable value (up to 1024).
- This function supports the following bearers carrying voice services: DRB, low-frequency SRB1, and low-frequency SRB2.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - **Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization**
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# Downlink Optimization---Fast MCS Index Reduction

- When the HARQ feedback for the initial transmission of voice services is NACK, the gNodeB decreases the CQI value by 1, 2, or 3 to reduce the downlink MCS index, thereby improving transmission reliability.
- The MCS index is gradually reduced to a value matching the channel quality by decreasing the CQI value several times. This function allows the gNodeB to quickly reduce the downlink MCS index by significantly decreasing the CQI value.
- The CQI adjustment value is specified by the **NRDUCellDlAmc.VoiceDlCqiAdjValue** parameter (which can be set to a maximum of 150). Fast MCS index reduction in the downlink decreases the downlink voice packet loss rate and improves voice transmission quality.

# Downlink Optimization---PDCCH CCE Aggregation Level Increase

- PDCCH CCE aggregation levels apply to both voice and data services. When a low PDCCH CCE aggregation level is selected and voice service UEs are located at the cell edge, the probability of missing DCI detection for voice services increases, leading to downlink voice packet loss.
- As such, the PDCCH CCE aggregation level can be increased by adjusting the PDCCH SINR and PDCCH BLER for voice services to reduce voice packet loss and improve voice service experience. Specifically,
  - The gNodeB deducts the SINR offset of voice services from the SINR used for PDCCH CCE aggregation level selection, thereby reducing the SINR of voice services.
  - The gNodeB is allowed to lower the PDCCH BLER specifically.





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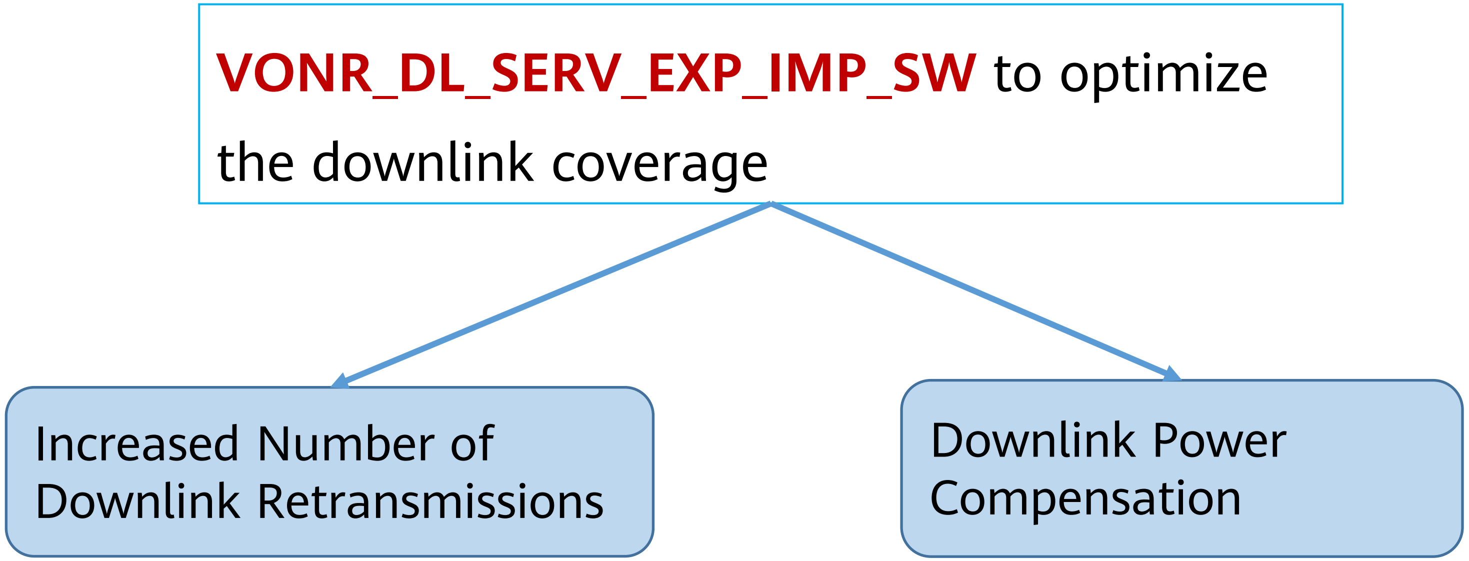
# Downlink Coverage Optimization

- The downlink coverage for VoNR services can be optimized by increasing the number of downlink retransmissions and compensating for downlink power. This optimization is enabled when the **VONR_DL_SERV_EXP_IMP_SW** option of the **NRDUCellDlSch.VoiceDlSchSwitch** parameter is selected.



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# Downlink Coverage Optimization---Retransmissions

- When 5QI 1 bearers work in UM, the gNodeB performs a maximum of four HARQ retransmissions at the MAC layer for voice service UEs.
- If a UE is located at the cell edge, four HARQ retransmissions may not be enough to ensure accurate downlink data transmission.
- To address this issue, this function allows for a maximum of seven HARQ retransmissions (eight HARQ transmissions) to increase downlink retransmission opportunities, thereby increasing the downlink data transmission success rate under weak coverage.

# Downlink Coverage Optimization---Power Compensation

- Before scheduling VoNR services in the downlink, the gNodeB estimates the number of required RBs based on the volume of voice services to be scheduled.
- If the estimated number is less than the total number of available RBs, the gNodeB will calculate the increase in the PDSCH power per RB based on the remaining power of the current cell.
- This enables downlink power compensation for VoNR UEs to improve their voice service experience.
- To avoid excessively high power spectral density (PSD), the gNodeB ensures that the increase in the PDSCH power per RB does not exceed 3 dB.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - **Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP**
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions

# Optimized Cooperation with BWP2 and DRX

- When VoNR is enabled together with BWP2 or DRX, cooperation between the functions can be optimized by selecting the **VONR_UE_PWR_SAVING_COOP_OPT_SW** option of the **NRDUCellAlgoSwitch.ServiceDiffSwitch** parameter.
- When this option is selected, the optimized cooperation with BWP2 and DRX is now supported. With this function:
  - BWP2 can be disabled when the number of VoNR UEs exceeds the UE number threshold.
  - DRX can be disabled before a 5QI 1 bearer is set up for a calling UE.
  - BWP2 or DRX can be disabled when channel quality deteriorates.
  - Disabling BWP2 in Congestion Scenarios
    **NRDUCellUePwrSaving.BwpPwrSavingSw=VONR_BWP2_CONGESTION_EXIT_SW**

# Disabling BWP2 Based on the Number of VoNR UEs

- Due to the limited bandwidth of BWP2, PDCCH resources and available PUSCH resources are insufficient, blocking voice packet scheduling, causing packet loss, and increasing the transmission delay. These problems become severe with an increased number of VoNR UEs.
- With this function, BWP2 can be disabled based on the number of VoNR UEs in the following scenarios:

Compare the number of VoNR UEs using BWP2 with the threshold

\>=

The gNodeB does not configure BWP2 for newly admitted VoNR UEs in the cell.
When a UE using BWP2 performs voice services in the cell, the gNodeB disables BWP2 for the UE.

<

The gNodeB allows VoNR UEs in the cell to switch between BWP1 and BWP2 when the switching conditions are met.



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# Disabling DRX Before 5QI 1 Bearer Setup

- When DRX takes effect, VoNR UEs cannot be scheduled during sleep time, increasing the voice packet transmission delay and causing packet loss.
- With this function, DRX takes effect with delay in the voice call setup procedure. That is, DRX does not take effect until a 5QI 1 bearer is set up for a calling UE.
- This reduces the voice bearer setup delay for the calling UE, compared with a voice call initiated by the calling UE in the DRX sleep time. DRX will take effect after a 5QI 1 bearer is set up for the UE.

# Disabling BWP2 or DRX Based on Channel Quality

- When channel quality deteriorates for VoNR UEs using BWP2 or in DRX mode in a cell, the gNodeB allows these UEs to switch from BWP2 to BWP1 or exit DRX mode to effectively reduce the transmission delay and packet loss, thereby improving voice quality.

The downlink CQI periodically reported by a VoNR UE is less than the threshold.

The uplink SINR of a VoNR UE is less than threshold.

Allow UE to switch from BWP2 to BWP1 or exit DRX mode





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# Disabling BWP2 in Congestion Scenarios

When congestion occurs due to insufficient BWP2 resources for VoNR UEs using BWP2 in a cell.

The gNodeB stops configuring BWP2 for newly admitted VoNR UEs

Prohibits VoNR UEs from switching to BWP2.

Improving voice quality





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# Optimized Cooperation with Intra-Base-Station UL CoMP

- Optimized cooperation between VoNR and intra-base-station UL CoMP is now supported.
- The gNodeB allows intra-base-station UL CoMP to take effect for VoNR UEs and raises the priority of VoNR UEs for intra-base-station UL CoMP to take effect, thereby improving the uplink transmission reliability and coverage capability for VoNR services in the overlapping area between cells.
- The procedure for intra-base-station UL CoMP to take effect for VoNR UEs is the same as that for other types of UEs.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - **Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration**
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions

# Exiting Gap-assisted Measurements

Inter-frequency or inter-RAT periodic reporting of MR

Fast ANR

PCI-specific ANR

Proactive PCI conflict detection based on intra-RAT ANR

Continuous gap-assisted measurements

Affect the voice service experience of VoNR UEs.

- For VoNR UEs (for which 5QI 1 bearers are set up) that have been selected to perform above measurements, the gNodeB will deliver an RRC Connection Reconfiguration message to remove the corresponding measurement procedure, thereby avoiding gap-assisted measurements.

# Prohibition of Measurement-based SCell Configuration

- Gap-assisted measurements are triggered when Scells are configured based on measurements for carrier aggregation (CA) UEs. However, scheduling is suspended during these measurements, affecting voice service experience.

- To prevent gap-assisted measurements from affecting voice service experience, the gNodeB is not allowed to deliver inter-frequency measurement configurations to reconfigure SCells after SCell removal or configure new SCells for UEs that initiate VoNR services before or after entering the CA state.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - **Inter-Cell CSI-RS for CM Interference Avoidance**
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions

# Inter-Cell CSI-RS for CM Interference Avoidance

- If the CSI-RS for channel measurement (CSI-RS for CM) time-frequency resources configured for the serving cell and its neighboring cells are different, the PDSCH of the serving cell and the CSI-RS for CM of the neighboring cells will interfere with each other, affecting the voice service experience of VoNR UEs.
- To address this issue, inter-cell CSI-RS for CM interference avoidance can be used to enable VoNR UEs in the serving cell to avoid interference (not schedule the PDSCH) at the time-frequency positions of periodic and aperiodic CSI-RS for CM transmitted in the neighboring cells.
- This avoids mutual interference between the PDSCH of the serving cell and the CSI-RS for CM of the neighboring cells.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - **Power Optimization in Handover Scenarios**
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions

# Power Optimization in Handover Scenarios

- VoNR UEs may experience handover failures in areas under interference or weak coverage, severely affecting voice services.
- To prevent such handover failures of VoNR UEs, the gNodeB needs to increase the random preamble power multiple times, which increases the handover delay or even results in handover failures.
- As such, configuration of the random preamble power offset is supported to increase the random preamble power for VoNR UEs during handovers, thereby reducing the handover delay and increasing the handover success rate.

NRDuCellUlPcConfig.VonrHoRanPreamblePwrOfs





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# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - **Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension**
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Added Performance Counters Related to VoNR Functions



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# Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension

- When scheduling is suspended abnormally, for example, due to downlink exceptions or expiration of the uplink time alignment timer, the gNodeB discards the VoNR packets after the downlink PDCP discard timer expires. However, these discarded voice packets are inappropriately counted during measurement of the counters related to PDCP packet loss listed in below table.

| Counter Name | Description |
|---|---|
| N.PDCP.DL.TrfSDU.TxPacket.Discard.Cell5QI | Number of discarded downlink PDCP packets for services with a specific 5QI in a cell. |
| N.PDCP.DL.TrfSDU.TxPacket.Discard | Number of discarded downlink PDCP SDUs in a cell. |

- Packet loss measurement in the case of abnormal scheduling suspension now excludes the voice packets discarded due to expiration of the downlink PDCP discard timer during measurement of the counters related to PDCP packet loss, making the counter measurement appropriate.





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# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - **Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells**
  - Added Performance Counters Related to VoNR Functions

# Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells

- When a VoNR UE is handed over to an inter-base-station cell that does not support VoNR, it may experience an RRC connection reestablishment or service drop due to intra-frequency interference during the handover, which in turn affects its voice service experience.
- This function enables the gNodeB to prohibit VoNR UEs from being handed over to inter-base-station intra- or inter-frequency neighboring NG-RAN cells that do not support VoNR.
  - For cell-level VoNR, this function is supported by deselecting the VONR_HO_SW option of the NRExternalNCell.MobilityFunInd parameter for external neighboring cells of the local cell.
  - For operator-level VoNR, this function is supported by deselecting the VONR_HO_SW option of the NRExternalNCellPlmn.MobilityFunInd parameter for external neighboring cells of the secondary operator.

# VoNR

- **New technologies for VoNR:**
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization: VoNR Performance Improvement in the Downlink & Downlink Coverage Optimization
  - Optimized Cooperation: BWP2 and DRX & Intra-Base-Station UL CoMP
  - Measurements: Exiting Gap-assisted Measurements & Prohibition of Measurement-based SCell Configuration
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Power Optimization in Handover Scenarios
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - **Added Performance Counters Related to VoNR Functions**

# Added Performance Counters Related to Basic VoNR Functions

- New performance counters related to basic VoNR functions have been added.

| Function SubSet | Counter Name | Description |
|---|---|---|
| 5QI QoS Flow Setup Measurement | N.QosFlow.FailEst.AMF.Cell5QI | Number of QoS flow setup failures with a specific 5QI due to core network faults in a cell. |
| | N.QosFlow.FailEst.RNL.Cell5QI | Number of QoS flow setup failures with a specific 5QI due to radio network layer faults in a cell. |
| | N.QosFlow.FailEst.TNL.Cell5QI | Number of QoS flow setup failures with a specific 5QI due to transport network layer faults in a cell. |
| 5QI QoS Flow Release Measurement | N.QosFlow.AbnormRel.RNL.Cell5QI | Number of abnormal QoS flow releases with a specific 5QI due to radio network layer faults in a cell. |
| | N.QosFlow.AbnormRel.TNL.Cell5QI | Number of abnormal QoS flow releases with a specific 5QI due to transport network layer faults in a cell. |
| | N.QosFlow.AbnormRel.HOFailure.Cell5QI | Number of abnormal QoS flow releases with a specific 5QI due to handover failures in a cell. |

# Added Performance Counters Related to Basic VoNR Functions(Cont.)

- New performance counters related to basic VoNR functions have been added.

| Function SubSet | Counter Name | Description |
|---|---|---|
| PDCP Measurement | N.Traffic.DL.ContinuousPktsLoss.Index0.5QI1 | Number of times the number of consecutively lost downlink packets with 5QI 1 falls into the range indicated by index 0. |
| | N.Traffic.DL.ContinuousPktsLoss.Index1.5QI1 | Number of times the number of consecutively lost downlink packets with 5QI 1 falls into the range indicated by index 1. |
| | N.Traffic.DL.ContinuousPktsLoss.Times.5QI1 | Number of calls with consecutively lost downlink packets with 5QI 1 in a cell. |
| | N.Traffic.UL.ContinuousPktsLoss.Index0.5QI1 | Number of times the number of consecutively lost uplink packets with 5QI 1 falls into the range indicated by index 0. |
| | N.Traffic.UL.ContinuousPktsLoss.Index1.5QI1 | Number of times the number of consecutively lost uplink packets with 5QI 1 falls into the range indicated by index 1. |
| | N.Traffic.UL.ContinuousPktsLoss.Times.5QI1 | Number of calls with consecutively lost uplink packets with 5QI 1 in a cell. |



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# Added Performance Counters Related to Coverage-based Adaptation Between VoNR and EPS Fallback

- Counter related to coverage-based adaptation between VoNR and EPS fallback have been added.

| Function SubSet | Counter Name | Description |
|---|---|---|
| Outgoing Inter-RAT Handover Measurement | N.VoiceFB.RespSucc.Cov<br>N.VoiceFB.RespSucc | Number of times gNodeB successfully responds to VoNR coverage-based voice fallback.<br>Number of times gNodeB successfully responds to VoNR voice fallback. |

Figure 1

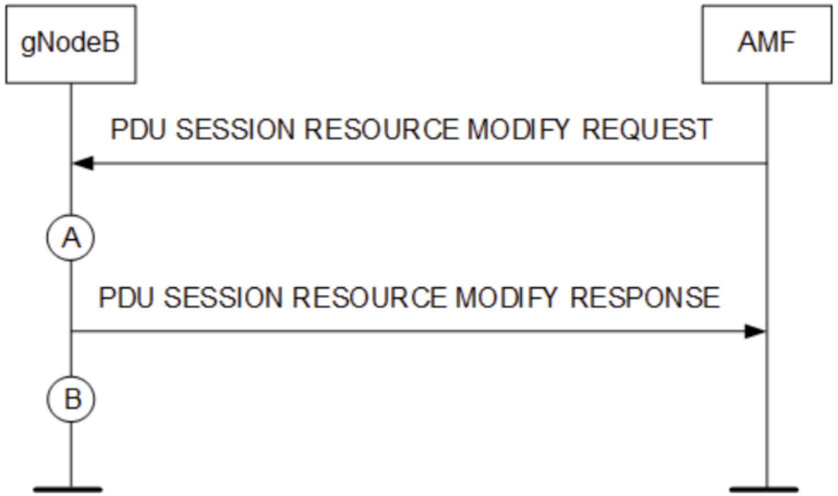
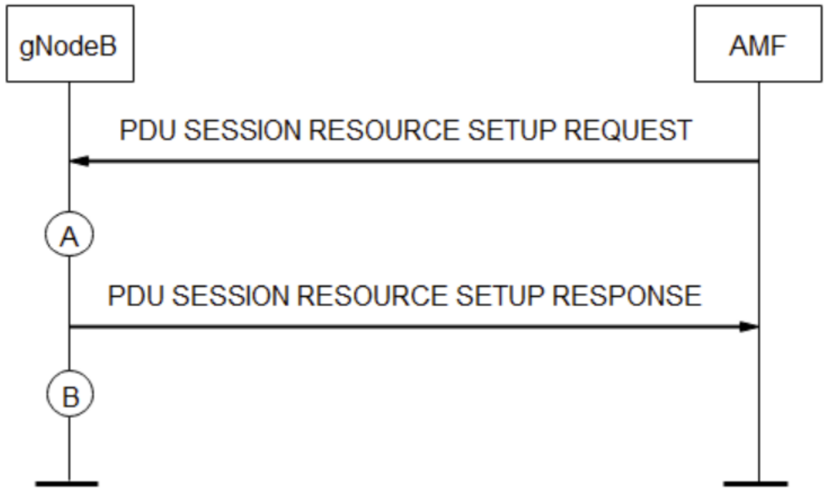



Figure 2



# Q&A

1. Which of the following descriptions are correct?

A. The maximum number of ARQ retransmissions in RLC AM is configurable now.

B. The gNodeB decreases the CQI value to reduce the downlink MCS index, thereby improving transmission reliability.

C. A maximum of seven HARQ retransmissions to increase the downlink data transmission success rate under weak coverage.

D. New counters are added for better performance monitor for VoNR services.

# Section Summary

- VoNR
  - Added Performance Counters Related to VoNR Functions
  - Prohibition of Handovers to Inter-Base-Station Non-VoNR Neighboring Cells
  - Optimized Packet Loss Measurement in the Case of Abnormal Scheduling Suspension
  - Power Optimization in Handover Scenarios
  - Inter-Cell CSI-RS for CM Interference Avoidance
  - Increase in the Maximum Number of RLC AM Retransmissions
  - Downlink Optimization
    - Fast MCS Index Reduction
    - PDCCH CCE Aggregation Level Increase
    - Downlink Coverage Optimization
      - Retransmissions
      - Power Compensation
  - Optimized Cooperation
    - With BWP2 and DRX
      - BWP2 can be disabled when the number of VoNR UEs exceeds the UE number threshold.
      - DRX can be disabled before a 5QI 1 bearer is set up for a calling UE.
      - BWP2 or DRX can be disabled when channel quality deteriorates.
      - Disabling BWP2 in Congestion Scenarios
    - With Intra-Base-Station UL CoMP
  - Measurements
    - Exiting Gap-assisted Measurements
    - Prohibition of Measurement-based SCell Configuration





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# Contents

## 2. Optional Features





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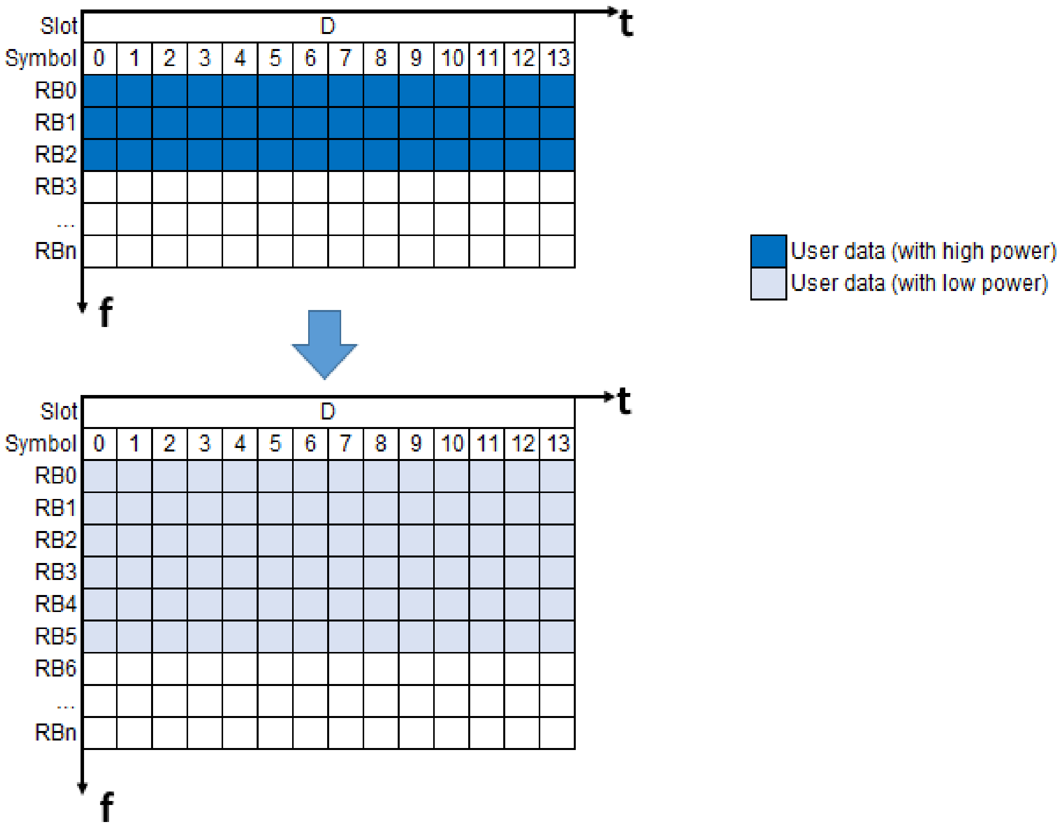
# Energy Saving Based on Flexible Frequency-Domain Scheduling

- With energy saving based on flexible frequency-domain scheduling, the transmit power is considered based on the configured period and load conditions when the PDSCH time-frequency resources are allocated in **light- or medium-load scenarios.** This reduces the energy consumption of the base station.

- Energy saving based on flexible frequency-domain scheduling reduces the power spectral density by lowering the MCS indexes and increasing the number of available RBs for target UEs. This saves energy.

**Figure 1** Working principles of energy saving based on flexible frequency-domain scheduling




## Support Scope and Dependency:

- Supported by AAUs and RRUs
- Supported by FDD and low-frequency TDD





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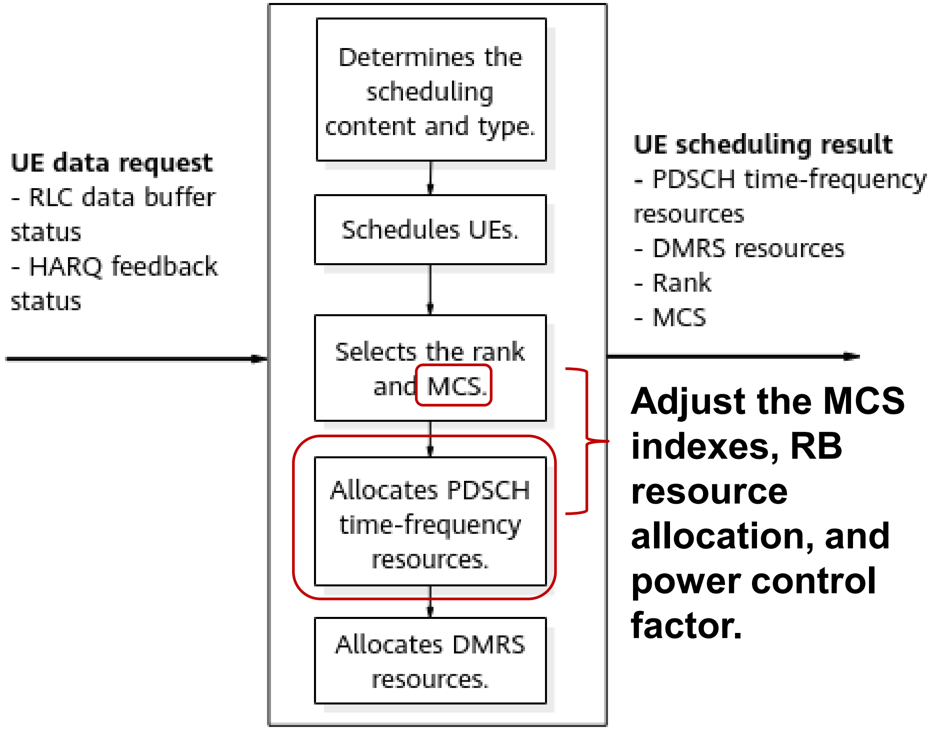
# Energy Saving Based on Flexible Frequency-Domain Scheduling

- Energy saving based on flexible frequency-domain scheduling enables the BTS to dynamically determine whether there are **idle RBs in each slot** during PDSCH scheduling. If there are idle RBs in a slot, the BTS **reduces the power spectral density** by **lowering the MCS indexes** & **increasing the number of available RBs** for target UEs, thereby saving energy. The # of available RBs to be increased is determined based on the # of remaining RBs and the max energy saving gains.
- **The PRB usage before this enabling the function + PRB usage after enabling this function - the extended PRB usage (equal to N.PRB.DL.DrbUsed.Avg minus N.PRB.DL.ExtendUsed.Avg).**
- Following UEs not effected by this feature: UEs in CoMP, coordinated scheduling (CS), coordinated beamforming (CBF), MU-MIMO, FWA, VoNR, Non-Slot, or high-reliability services, UEs performing delay-sensitive services, frequency-selective UEs, and UEs performing full buffer services in drive tests.




**Procedure of downlink scheduling**

# Network Impacts

## Positive Impact

- If symbol power saving is enabled and a typical 64T AAU is used, energy saving based on flexible frequency-domain scheduling provides 0% to 1%, 1% to 3%, and 2% to 4% gains when the DRB usage is less than 10%, 10% to 30%, and 30% to 50%, respectively.
- The base station has basic power consumption and dynamic power consumption. Energy saving based on flexible frequency-domain scheduling reduces the dynamic power consumption. This function delivers low power saving gains in light-load scenarios because the proportion of dynamic power consumption is low in such cases. The gains increase in medium-load scenarios due to a higher proportion of dynamic power consumption. The gains decrease in heavy-load scenarios because there are fewer remaining frequency-domain resources.
- The lower the basic power consumption of RF modules, the higher the gains (in the unit of %) provided by energy saving based on flexible frequency-domain scheduling.

## Impact Analysis

- This function has no impact on network KPIs under different load conditions. It can be enabled all day long with different load conditions.
- The average MCS index for downlink scheduling decreases.
- In a common cell, the values of the following counters related to the downlink PRB usage increase: N.PRB.DL.DrbUsed.Avg and N.PRB.DL.ExtendUsed.Avg.
- In a hyper cell or combined cell, the values of the following counters related to the downlink PRB usage of a TRP increase: N.HyperCell.TRP.PRB.DL.Used.Avg and N.HyperCell.TRP.PRB.DL.ExtendUsed.Avg.
- After interference randomization is enabled, the interference between the local cell and its neighboring cells and IBLER of the local cell increase in light-load scenarios.





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# Usage Guide

## Recommended Scenarios

- Energy saving based on flexible frequency-domain scheduling can be enabled all day long with different load conditions.
- Both the default and recommended values of the **DlPrbThld** parameter are **40** because this function delivers the maximum gains in medium-load scenarios.

## Activation

```
//Enabling energy saving based on flexible frequency-domain scheduling
MOD NRDUCELLALGOSWITCH: NrDuCellId=0, PowerSavingSwitch=FLEX_FREQ_SCH_ENERGY_SAVING_SW-1;
//Setting an energy saving policy of energy saving based on flexible frequency-domain scheduling
ADD NRDUCELLPOWERSAVING: NrDuCellId=0, PowerSavingPolicyIndex=0, StartTime=01&00&00, StopTime=03&00&00,
PowerSavingType=FLEX_FREQ_SCH_ENERGY_SAVING, DlPrbThld=40, DlPrbOffset=10;
```

## Deactivation

```
//Disabling energy saving based on flexible frequency-domain scheduling
MOD NRDUCELLALGOSWITCH: NrDuCellId=0, PowerSavingSwitch=FLEX_FREQ_SCH_ENERGY_SAVING_SW-0;
//Removing an energy saving policy of energy saving based on flexible frequency-domain scheduling
RMV NRDUCELLPOWERSAVING: NrDuCellId=0, PowerSavingPolicyIndex=0;
```



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# Verification of the Feature

## Activation Verification

- Run the **LST NRDUCELLALGOSWITCH** command. Verify that the value of **Power Saving Switch** is **Flexible Freq Sch for Energy Saving Sw:On** in the command output.
- Run the **LST NRDUCELLPOWERSAVING** command. Verify that there is at least one record with **Power Saving Type** being **Flexible Freq Sch for Energy Saving**.
- Run the **DSP NRDUCELL** command. Verify that the value of **Power Saving State** is **Flexible Freq Sch for Energy Saving:Enabled**, indicating that energy saving based on flexible frequency-domain scheduling has taken effect.

## Counters

| Counter Name | Counter ID | Description |
|---|---|---|
| VS.EnergyCons.BTS.Adding.NR | 1593835804 | The rated power consumption of each board of the gNodeB is sampled. The sum of these sampling results is used as the value of the counter (cumulative method). |
| VS.EnergyCons.BTSBoard | 1593835836 | This counter provides the power consumption of each RRU/RFU/AAU within a measurement period. |
| N.PRB.DL.ExtendUsed.Avg | 1911831550 | Average number of extended PRBs used on the PDSCH |
| N.HyperCell.TRP.PRB.DL.ExtendUsed.Avg | 1911831599 | Average number of extended PRBs used by downlink channels of a TRP for hyper cells |

# Contents

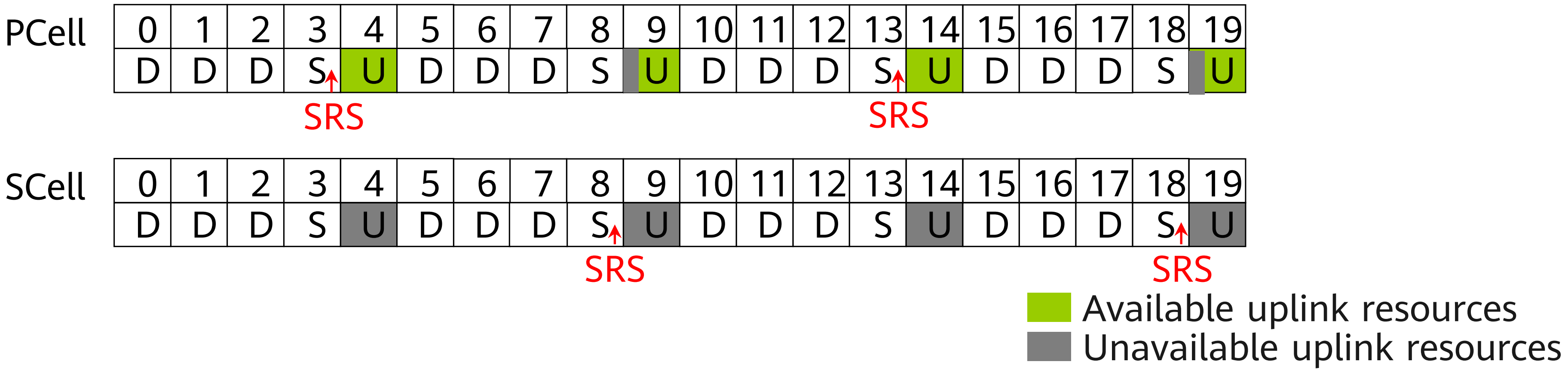
## 2. Optional Features

# The Background of CA SRS Carrier Switching

- There are two types of SCCs, uplink+downlink SCCs and downlink-only SCCs.
  - In SCells on uplink+downlink SCCs (uplink+downlink SCells), SRS measurements are available, and therefore downlink beamforming performance in these SCells is the same as that in PCells.
  - SCells on downlink-only SCCs (downlink-only SCells) lack SRS-based weights and have to use PMI-based weights. This compromises downlink beamforming performance in TDD downlink-only SCells.

# CA SRS Carrier Switching

- Both intra-band CA and intra-FR inter-band CA support CA SRS carrier switching. The principles are as follows:
  - With this function, the uplink RF module of a UE sends SRSs in the PCell and a TDD downlink-only SCell in turn so that SRS-based information is available to the SCell.
  - SRS carrier switching is controlled by the **SRS_CARRIER_SWITCHING_SW** option of the **NRDUCellCarrMgmt**.CaEnhancedAlgoSwitch parameter. In NSA networking, the **SRS_CARR_SWITCH_CAPB_QUERY_SW** option of the **NsaDcAlgoParam**.NsaDcAlgoSwitch parameter must also be selected on the LTE side.



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# Network Analysis of CA SRS Carrier Switching

- Benefits
  - After SRS carrier switching is enabled, SRS-based weights instead of PMI-based weights are used in SCells. This increases the downlink throughput of UEs in their TDD SCells. A shorter SRS transmission interval in SCells leads to a higher gain, and a longer interval leads to a smaller gain.
- Impacts
  - After an SCell is activated for a UE, uplink services are interrupted when the UE sends SRSs on two carriers in turn, affecting the uplink throughput of the UE in the PCell. The uplink throughput is no longer affected once the SCell is deactivated.
  - If the load is heavy, the number of RRC connection reconfigurations over the air interface and the values of related counters increase.

# CA SRS Carrier Switching Deployment

- SRS carrier switching has the following requirements for UEs:
  - UEs must support **SRS carrier switching**. That is, the UE-reported capability information must include the **SRS-SwitchingTimeNR** IE.
  - UE must support **antenna switching**. That is, the UE-reported capability information must include the **SupportedSRS-TxPortSwitch** IE.
  - The UE-reported capability information must include the SRS resource capability in the target band of SRS carrier switching, that is, the **supportedSRS-Resources** IE in FeatureSetDownlink-v15a0.
  - The value of **switchingTimeDL** reported by UEs is less than or equal to the value of the **NRDUCellCarrMgmt.SrsCarrSwitchingTimeDlThld** parameter.
  - The value of **switchingTimeUL** reported by UEs is less than or equal to the value of the **NRDUCellCarrMgmt.SrsCarrSwitchingTimeUlThld** parameter.



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# CA SRS Carrier Switching Deployment (Cont.)

- Licenses
  - Feature licenses:

| Feature ID | Feature Name | Model | Sales Unit |
|---|---|---|---|
| FOFD-050206 | CA SRS Carrier Switching | NR0S00CAWW00 | per Cell |





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# CA SRS Carrier Switching Activation

- Activation
  - //Enabling SRS carrier switching in NSA networking. *This command is a high-risk command.*
  - MOD NSADCALGOPARAM: NsaDcAlgoSwitch=SRS_CARR_SWITCH_CAPB_QUERY_SW-1;
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoSwitch=SRS_CARRIER_SWITCHING_SW-1;
  - //Enabling SRS carrier switching in SA networking. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoSwitch=SRS_CARRIER_SWITCHING_SW-1;
  - //Setting the number of uplink symbols in a self-contained slot in the FDD PCell for SRS carrier switching in the scenario where an FDD cell serves as the PCell and a TDD cell serves as an Scell. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, SrsSwitchingSccSSlotUNum=ALLOWED_S_SLOT_U_NUM_2-1;

# CA SRS Carrier Switching Activation and Deactivation

- Activation
  - //Turning on the switch for prolonging SRS periods for CA UEs. If this switch is turned off, SCells may have no SRS resources. *This command is a high-risk command.*
  - MOD NRDUCELLSRS: NrDuCellId=0, SrsAlgoExtSwitch=CARR_AGG_SRS_ALLOC_SW-1;
- Deactivation
  - //Disabling SRS carrier switching in NSA networking. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoSwitch=SRS_CARRIER_SWITCHING_SW-0;
  - MOD NSADCALGOPARAM: NsaDcAlgoSwitch=SRS_CARR_SWITCH_CAPB_QUERY_SW-0;
  - //Disabling SRS carrier switching in SA networking. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaEnhancedAlgoSwitch=SRS_CARRIER_SWITCHING_SW-0;

# CA SRS Carrier Switching Verification

- Activation verification
  - Start Uu signaling tracing on the MAE as follows: Log in to the MAE and choose Monitor > **Signaling Trace** > **Signaling Trace Management**. On the displayed page, choose Trace Type > NR > **Application Layer** > **Uu Interface Trace**.
  - Enable a UE to access the network and check the fields in the SCellConfig IE in the **RRCReconfiguration** message delivered by the gNodeB **during SCell configuration**. If the IE contains the srs-Config field, this function has taken effect.



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# Q&A

1. When the CA SRS carrier switching of intra-FR inter-band CA is enabled, the uplink RF module of a UE sends SRSs in the PCell and a TDD downlink-only SCell in turn so that SRS-based information is available to the SCell.

A. TRUE

B. FALSE

# Contents

## 2. Optional Features

# Background of Experience Boosting based on Multi-Band Coordination

- UEs do not currently report inter-frequency spectral efficiency information to the serving gNodeB. As a result, the carriers selected by the base stations for UEs may not be able to provide the optimal user experience.

**The experience-based smart carrier selection function**

gNodeB adaptively selects carriers capable of providing optimal user experience for UEs based on a variety of factors.

In areas with weak uplink coverage, measurement reports from UEs may fail to reach the gNodeB as the radio environment deteriorates, resulting in the failure for experience-based smart carrier selection to take effect.

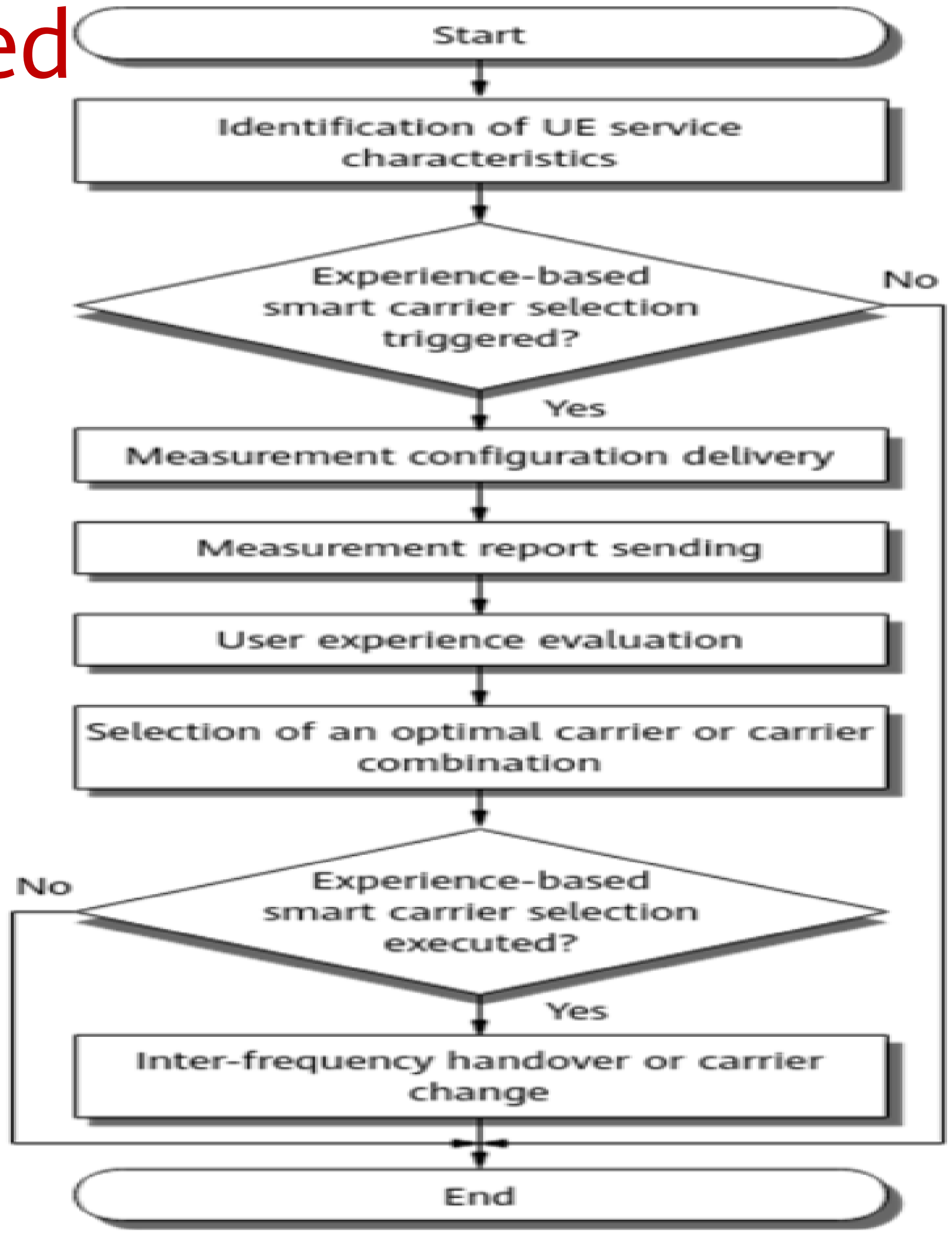
**Protection of UEs under weak uplink coverage**

# Experience Boosting based on Multi-Band Coordination

- **New technologies:**
  - **Experience-based Smart Carrier Selection**
  - Protection of UEs Under Weak Uplink Coverage

# Basic process of experience-based smart carrier selection

- the gNodeB considers a variety of factors including cell coverage, bandwidth, and load to select carriers or carrier combinations that provide the optimal user experience for UEs.



# UE Service Characteristics Identification

- The gNodeB identifies UEs with different service characteristics based on the uplink and downlink traffic volumes of UEs.

<table>
<tr><th>Traffic Volume</th><th colspan="2">UE Identification Result</th></tr>
<tr><td>Large uplink traffic volume and small downlink traffic volume</td><td colspan="2">The UE is running uplink-preferred services.</td></tr>
<tr><td>Small uplink traffic volume and large downlink traffic volume</td><td colspan="2">The UE is running downlink-preferred services.</td></tr>
<tr><td>Small uplink traffic volume and small downlink traffic volume</td><td colspan="2">The experience-based smart carrier selection function does not take effect.</td></tr>
<tr><td rowspan="2">Large uplink traffic volume and large downlink traffic volume</td><td>The uplink traffic volume is at least 30 times the downlink traffic volume</td><td>The UE is an uplink-preferred UE.</td></tr>
<tr><td>The downlink traffic volume at least 30 times the uplink traffic volume</td><td>The UE is an downlink-preferred UE.</td></tr>
</table>

# Triggering of Experience-based Smart Carrier Selection

| Triggering Mode | Triggering Condition |
|---|---|
| By traffic model | After a UE accesses the network, experience-based smart carrier selection will be triggered for the UE when the traffic volume in either the uplink or downlink increases. |
| | When the service characteristics (uplink- or downlink-preferred) of a UE change, experience-based smart carrier selection will be triggered for the UE. |
| By weak uplink coverage | The gNodeB checks the SRS SINR of each UE with heavy uplink traffic in its serving cell every 15s. If the SRS SINR of a UE is less than the SRS SINR threshold, experience-based smart carrier selection will be triggered for the UE. |
| Periodically | If the air interface capability for an uplink- or downlink-preferred UE degrades in the corresponding direction by over 30% when the timer expires, compared with when the last smart carrier selection was performed, experience-based smart carrier selection will be triggered for the UE. |

# Measurement Configuration Delivery

- The gNodeB can deliver measurement configurations for a maximum of four neighboring frequencies to a UE. When experience-based smart carrier selection is triggered for a UE meeting the QCI requirement, the gNodeB delivers inter-frequency **event A5** measurement configurations related to the frequencies to be measured all together to the UE.

| UE Type | Frequency Selection |
|---|---|
| Single-carrier UEs, and multi-carrier UEs supporting super uplink | The gNodeB selects a maximum of four frequencies for inter-frequency measurement from the NR frequencies specified by the **NRCellFreqRelation**.SsbDescMethod and **NRCellFreqRelation**.SsbFreqPos parameters based on the frequency priorities for RRC_CONNECTED UEs. |
| Multi-carrier UEs supporting carrier aggregation | The gNodeB preferentially selects the NR frequencies for measurement from the NR frequencies specified by the **NRCellFreqRelation**.SsbDescMethod and **NRCellFreqRelation**.SsbFreqPos parameters. If the number of NR frequencies that can be delivered is less than four, the gNodeB selects more frequencies from the CA frequency group. |

# Measurement Reporting

- If the UE sends measurement reports for all neighboring frequencies contained in the measurement configurations within three seconds after the configurations are delivered, user experience evaluation will start.
- If the UE has measured neighboring frequencies based on inter-frequency measurement event A5 for three seconds but no cell on a neighboring frequency meets conditions, the gNodeB deletes this inter-frequency event A5 measurement configuration for this neighboring frequency so that the UE stops the current inter-frequency event A5 measurements. Then, user experience evaluation is started for the UE.

# User Experience Evaluation

- Cell selection for candidate carriers or candidate carrier combinations
  - The gNodeB selects cells based on the received inter-frequency event A5 measurement reports. That is, it selects the cells that meet the conditions below from the cells each with the highest RSRP value on the corresponding neighboring frequencies. The gNodeB evaluates the user experience in the serving cell and in these selected cells.

| Selection Condition | Experience Evaluation |
|---|---|
| The RSRP is greater than or equal to the RSRP threshold for interference-based inter-frequency handovers. | The cell can be selected as a candidate carrier or as a primary component carrier (PCC) in a candidate carrier combination for user experience evaluation. |
| The RSRP is greater than or equal to threshold 2 for event A5 related to SCell configuration for CA. | The cell can be selected as a secondary component carrier (SCC) in a candidate carrier combination for user experience evaluation. |





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# User Experience Evaluation --- Downlink Air Interface Capability

- Downlink air interface capability evaluation for downlink-preferred UEs.

| Evaluation Factor | Description |
|---|---|
| UE-specific downlink spectral efficiency | UE-specific downlink spectral efficiency is considered in the downlink air interface capability calculation only if the switch for spectral efficiency prediction oriented to downlink experience evaluation is turned on,<br>and the gNodeB can predict the downlink spectral efficiency of each frequency using virtual grid models. |
| Equivalent downlink cell bandwidth | It is calculated based on factors such as the downlink cell bandwidth and UE-supported downlink bandwidth. |
| Downlink load factor | It is calculated based on the number of UEs to be scheduled in the downlink per second. |



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# User Experience Evaluation --- Uplink Air Interface Capability

- Uplink air interface capability evaluation for uplink-preferred UEs, and equivalent cell bandwidth evaluation.

| Evaluation Dimension | Evaluation Factor | Description |
|---|---|---|
| Uplink air interface capability | UE-specific uplink spectral efficiency | The uplink spectral efficiency of a UE in an inter-frequency candidate cell is calculated based on the uplink spectral efficiency of the UE in its serving cell and the differences in the path loss, interference, and number of uplink receive antennas between the serving and candidate cells. |
| | Cell-specific number of remaining uplink RBs | It is calculated based on the accumulated number of remaining RBs on the PUSCH per second in the cell involved. |
| Equivalent cell bandwidth | Equivalent cell bandwidth | It is calculated based on factors such as the cell bandwidth and UE-supported bandwidth. |





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# Optimal Carrier or Carrier Combination Selection

- For an uplink- or downlink-preferred UE, the following factors are evaluated in sequence:
  - uplink/downlink air interface capability, handover, carrier change, equivalent uplink/downlink cell bandwidth, and number of uplink/downlink carriers.

| Factors for Evaluation | Evaluation Principle |
|---|---|
| Air interface capability | Candidate carriers or carrier combinations with a higher air interface capability have a higher priority. |
| Handover | A handover transiently interrupts data transmission. Therefore, candidate carrier combinations that do not involve a handover has a higher priority. |
| Carrier change | A carrier change transiently interrupts data transmission. Therefore, candidate carrier combinations that do not involve an SCC change have a higher priority. |
| Equivalent cell bandwidth | Candidate carriers or carrier combinations with a larger equivalent cell bandwidth have a higher priority. |
| Number of carriers | In the case of multi-carrier UEs, the smaller the number of carriers for aggregation in a candidate carrier combination, the lower the consumption of channel resources such as physical downlink control channel (PDCCH) and PUCCH resources. Therefore, candidate carrier combinations with a smaller number of carriers have a higher priority. |

# Execution of Experience-based Smart Carrier Selection

- If the selected optimal carrier or carrier combination is different from the current carrier or carrier combination, a handover or carrier change is performed.
  - For a single-carrier UE, a handover to the target cell will be initiated directly.
  - For a multi-carrier UE that supports CA or super uplink:
    - If the PCC in the optimal carrier combination is different from the current PCC, a handover to the target cell is initiated. During the handover, the SCCs or SUL carriers in the optimal carrier combination will be configured for the UE involved.
    - If the PCC in the optimal carrier combination is the current PCC, the gNodeB sends an RRCReconfiguration message to change the SCCs or SUL carriers for the UE involved.

# Policies of Experience-based Smart Carrier Selection

**NRCellCaMgmtConfig.SmartCarrSelPolicy** parameter

**EXPERIENCE_FIRST**

gNodeB selects an optimal carrier or carrier combination for any UE based on user experience, no matter whether the UE is a cell-center or cell-edge UE.

**NEAR_POINT_FIXED_ANCHOR**

This policy differentiates between cell-center UEs and cell-edge UEs.

It is recommended that frequency-priority-based inter-frequency handover be enabled so that fixed anchors can be selected for cell-center UEs.

Cell-Center Fixed Anchor Policy

# Cell-Center Fixed Anchor Policy

- Cell-center UE and cell-edge UE identification:
  - After a UE accesses a cell, the gNodeB identifies it as a cell-edge UE by default and delivers an event A1 configuration to it.
  - After receiving an event A1 report, the gNodeB identifies the UE as a cell-center UE, deletes the event A1 configuration, and delivers an event A2 configuration.
  - After receiving an event A2 report, the gNodeB identifies the UE as a cell-edge UE, deletes the event A2 configuration, and delivers the event A1 configuration.
- Carrier or carrier combination selection for cell-center UEs and cell-edge UEs:
  - If the UE is a cell-center UE, the PCC or serving cell of the UE will not be changed, and only optimal SCCs will be selected for the UE.
  - If the UE is a cell-edge UE, an optimal carrier or carrier combination is selected based on the experience-first policy.

# Benefits of Experience-based Smart Carrier Selection

- The average uplink and downlink UE throughputs increase.
- This function brings greater benefits to networks with more frequencies, larger coverage difference between frequency bands, larger load difference between cells, or larger UE traffic volumes.

# Experience-based Smart Carrier Selection Activation

- Activation command examples:
  - //Turn on the Multi-Frequency Smart Selection Switch. (This is a high-risk command.)
    - MOD NRCELLALGOSWITCH: NrCellId=0, MultiFreqAlgoSwitch=MULTI_FREQ_SMART_SEL_SW-1;
  - //Set the experience-first policy for smart carrier selection.
    - MOD NRCELLCAMGMTCONFIG: NrCellId=0, SmartCarrSelPolicy=EXPERIENCE_FIRST;
  - //Set the downlink experience evaluation hysteresis for smart carrier selection.
    - MOD NRCELLCAMGMTCONFIG: NrCellId=0, DlExpEvalHyst=20;
  - //Set the uplink experience evaluation hysteresis for smart carrier selection.
    - MOD NRCELLCAMGMTCONFIG: NrCellId=0, UlExpEvalHyst=20;
  - //Set the uplink experience evaluation factor for the cell. (This is a high-risk command.)
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, UlCellExpEvaluationFactor=0;



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# Experience-based Smart Carrier Selection Deactivation

- Deactivation command examples:
  - Turn off the Multi-Frequency Smart Selection Switch. (This is a high-risk command.)
    - MOD NRCELLALGOSWITCH: NrCellId=0, MultiFreqAlgoSwitch=MULTI_FREQ_SMART_SEL_SW-0;

# Activation Verification

- After experience-based smart carrier selection is activated, observe the counters listed in the following table. If any of the counters produces a non-zero value, this function has taken effect.

| Counter ID | Counter Name |
|---|---|
| 1911833645 | N.MultiFreqSmartSel.Exec |
| 1911833646 | N.MultiFreqSmartSel.Exec.CA |
| 1911833846 | N.MultiFreqSmartSel.DlIntraFreqSEModel.Exec |
| 1911833847 | N.MultiFreqSmartSel.DlIntraFreqSEModel.Exec.CA |



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# Q&A

1. What are the three triggering modes of experience-based smart carrier selection?

# Q&A

2. What is the maximum number of frequencies for which a gNodeB can deliver measurement configurations for inter-frequency measurements?

   A. 3

   B. 4

   C. 5

# Q&A

3. For a downlink-preferred UE, which of the following items need to be used to calculate and evaluate the downlink air interface capability?

   A. UE-specific downlink spectral efficiency

   B. Equivalent downlink cell bandwidth

   C. Downlink load factor

   D. Cell-specific number of remaining downlink RBs

# Q&A

4. For a downlink-preferred UE, the optimal carrier or carrier combination is determined based on the following factors in sequence: downlink air interface capability, carrier change, handover, equivalent downlink cell bandwidth, and number of downlink carriers.

   A. True

   B. False

# Experience Boosting based on Multi-Band Coordination

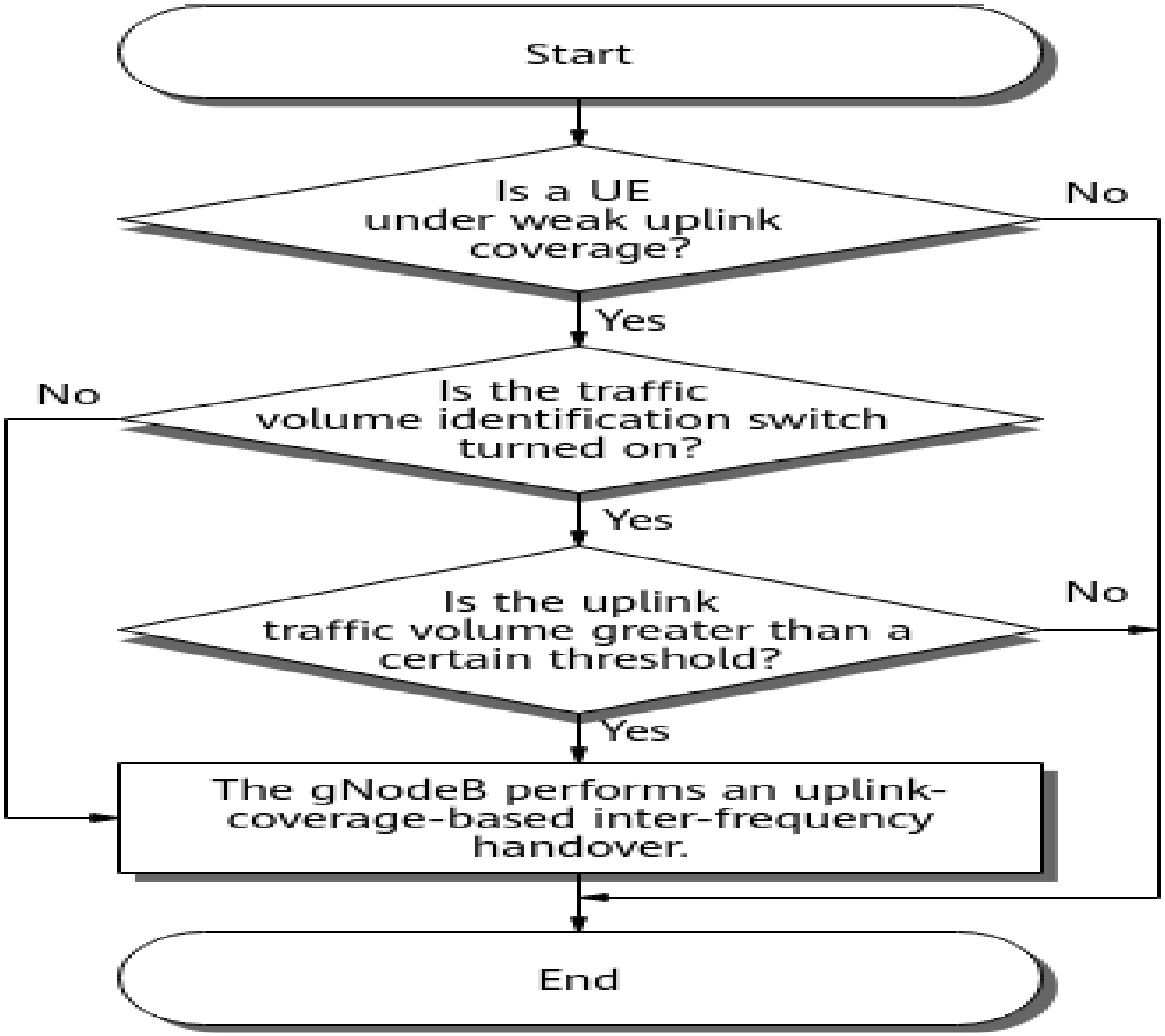
- **New technologies:**
  - Experience-based Smart Carrier Selection
  - **Protection of UEs Under Weak Uplink Coverage**

# Protection of UEs Under Weak Uplink Coverage

- The protection of UEs under weak uplink coverage function identifies UEs under weak uplink coverage and hands over these UEs to inter-frequency cells, which ensures service continuity for these UEs.
- The protection of UEs under weak uplink coverage function involves two phases:
  - Identification of target UEs under weak uplink coverage
  - Uplink-coverage-based inter-frequency handover

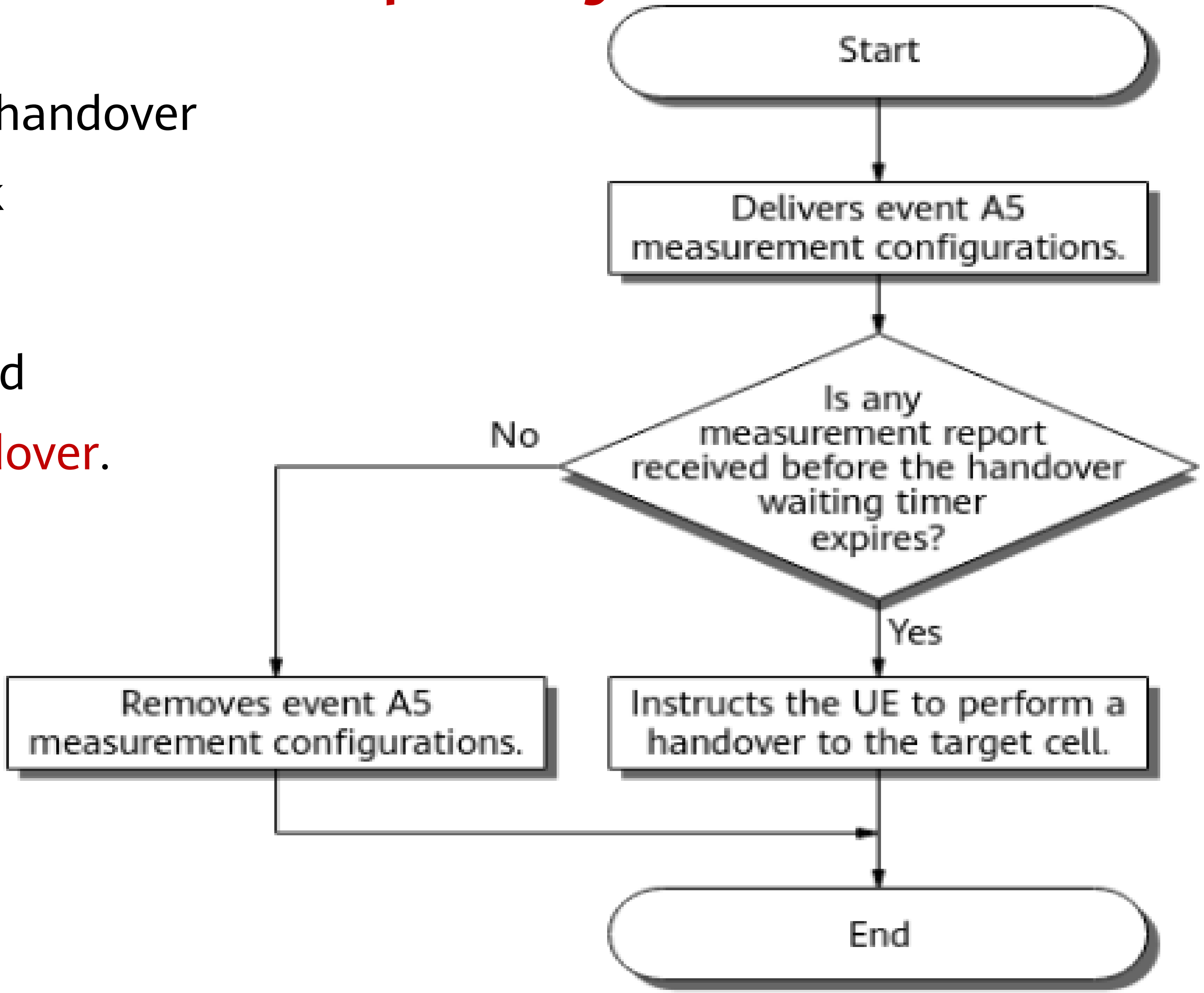
# Identification of Target UEs Under Weak Uplink Coverage

- The gNodeB periodically identifies target UEs under weak uplink coverage. The figure shows the identification procedure in a period.



# Uplink-Coverage-based Inter-Frequency Handover

- Uplink-coverage-based inter-frequency handover applies to target UEs under weak uplink coverage.
- This function allows measurement-based handover but does not allow blind handover.



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# Benefits of Protection of UEs Under Weak Uplink Coverage

- The average uplink UE throughput increases.
- The service drop rate decreases when both the switch for protection of UEs under weak uplink coverage and the traffic volume identification switch are turned on and the uplink SINR low threshold for transferring UEs from NR to E-UTRAN and the threshold for identifying common uplink large packets are properly set.

# Using MML Commands

- Activation command examples:
  - //In FDD, configure a frequency relationship for the NR cell involved.
    - ADD NRCELLFREQRELATION: NrCellId=0, SsbFreqPos=8000, SsbDescMethod=SSB_DESC_TYPE_GSCN, FrequencyBand=N77, SubcarrierSpacing=30KHZ, ConnFreqPriority=16;
  - //In FDD, configure parameters related to an external cell.
    - ADD NREXTERNALNCELL: Mcc="302", Mnc="220", gNBId=1, CellId=0, CellName="A", PhysicalCellId=0, Tac=0, SsbDescMethod=SSB_DESC_TYPE_GSCN, SsbFreqPos=8000, FrequencyBand=N77, NrNetworkingOption=UNLIMITED;
  - //In FDD, configure a frequency relationship for the NR cell involved.
    - ADD NRCELLFREQRELATION: NrCellId=0, SsbFreqPos=4625, SsbDescMethod=SSB_DESC_TYPE_GSCN, FrequencyBand=N3, SubcarrierSpacing=15KHZ, ConnFreqPriority=16;

# Using MML Commands (Cont.)

- Activation command examples:
  - //In TDD, configure parameters related to an external cell.
    - ADD NREXTERNALNCELL: Mcc="302", Mnc="220", gNBId=1, CellId=0, CellName="A", PhysicalCellId=0, Tac=0, SsbDescMethod=SSB_DESC_TYPE_GSCN, SsbFreqPos=4625, FrequencyBand=N3, NrNetworkingOption=UNLIMITED;
  - //(Optional) Add a PLMN list for the external NR cell in RAN sharing with common carrier mode
    - ADD NREXTERNALNCELLPLMN: Mcc="302", Mnc="220", gNBId=1, CellId=0, SharedMcc="460", SharedMnc="03", Tac=0, NrNetworkingOption=SA;
  - //Set NR cell relationship parameters.
    - ADD NRCELLRELATION: NrCellId=0, Mcc="302", Mnc="220", gNBId=1, CellId=0, CellIndividualOffset=DB0;

# Using MML Commands (Cont.)

- Activation command examples:
  - //Configure a group of measurement parameters for inter-frequency handovers.
    - MOD NRCELLINTERFHOMEAGRP: NrCellId=0, InterFreqHoMeasGroupId=0, InterFreqA4A5TimeToTrig=320MS, InterFreqA4A5Hyst=2, UlCovInterFreqA5RsrpThld1=-110, CovInterFreqA5RsrpThld2=-106;
    - MOD NRCELLINTERFHOMEAGRP: NrCellId=0, InterFreqHoMeasGroupId=1,InterFreqA4A5TimeToTrig=320MS, InterFreqA4A5Hyst=2, UlCovInterFreqA5RsrpThld1=-110, CovInterFreqA5RsrpThld2=-106;
  - //(Optional) Set QCI-specific measurement parameters.
    - MOD NRCELLQCIBEARER: NrCellId=0, Qci=1, InterFreqHoMeasGroupId=0;
    - MOD NRCELLQCIBEARER: NrCellId=0, Qci=9, InterFreqHoMeasGroupId=1;



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# Using MML Commands (Cont.)

- Activation command examples:
  - //Configure QCI priorities for handovers.
    - MOD GNBQCIBEARER: Qci=1, QciPriorityForHo=1;
    - MOD GNBQCIBEARER: Qci=9, QciPriorityForHo=7;
  - //Select the INTER_FREQ_HO_CAPB_IND_OPT_SW option. (This is a high-risk command.)
    - MOD GNBMOBILITYCOMMPARAM: ProtocolCompatibilitySw=INTER_FREQ_HO_CAPB_IND_OPT_SW-1;
  - //Set the uplink SINR threshold for NR inter-frequency handovers.
    - MOD NRDUCELLSRSMEAS: NrDuCellId=0, NrToEutranSinrLowThld=-30;
  - //(Optional) Turn on the traffic volume identification switch. (This is a high-risk command.)
    - MOD NRCELLALGOSWITCH: NrCellId=0, ServiceFunctionSwitch=VOLUME_IDENTIFY_SW-1;

# Using MML Commands (Cont.)

- Activation command examples:
  - //(Optional) Configure the uplink traffic volume threshold. (This is a high-risk command.)
    - MOD NRDUCELLSERVEXP: NrDuCellId=0, CommonUlLargePktIdentThld=80;
  - //(Optional) Configure the NSA UL Path Select SINR Time-to-Trigger parameter.
    - MOD NRDUCELLSRSMEAS: NrDuCellId=0, NsaUlPathSelSinrTimeToTrig=10;
  - //(Optional) Configure the NSA/SA Selection Opt Period parameter. (This is a high-risk command.)
    - MOD GNODEBPARAM: NsaSaSelOptPeriod=60;
  - //Turn on the switch for protection of UEs under weak uplink coverage. (This is a high-risk command.)
    - MOD NRCELLALGOSWITCH: NrCellId=0, MultiFreqAlgoSwitch=UL_WEAK_COV_UE_PROTECT_SW-1;



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# Using MML Commands (Cont.)

- Deactivation command examples:
  - //Turn off the switch for protection of UEs under weak uplink coverage. (This is a high-risk command.)
    - MOD NRCELLALGOSWITCH: NrCellId=0, MultiFreqAlgoSwitch=UL_WEAK_COV_UE_PROTECT_SW-0;

# Activation Verification

- After the protection of UEs under weak uplink coverage function is activated, observe the counters listed in the following table. If any of the counters produces a non-zero value, this function has taken effect.

| Counter ID | Counter Name |
|---|---|
| 1911833798 | N.HO.InterFreq.ULCoverage.PrepAttOut |
| 1911833799 | N.HO.InterFreq.ULCoverage.ExecAttOut |
| 1911833800 | N.HO.InterFreq.ULCoverage.ExecSuccOut |



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# Q&A

1. What are the phases involved in the protection of UEs under weak uplink coverage function?

# Q&A

2. The gNodeB periodically identifies target UEs under weak uplink coverage.

   A. True

   B. False

# Q&A

3. Uplink-coverage-based inter-frequency handover supports both measurement-based mode and blind mode.

   A. True

   B. False

# Section Summary

- Experience Boosting based on Multi-Band Coordination
  - The basic process of experience-based smart carrier selection function
    - UE Service Characteristics Identification
    - Triggering of Experience-based Smart Carrier Selection
    - Measurement Configuration Delivery
    - Measurement Reporting
    - User Experience Evaluation
    - Optimal Carrier or Carrier Combination Selection
    - Execution of Experience-based Smart Carrier Selection
    - Policies of Experience-based Smart Carrier Selection
  - Protection of UEs under weak uplink coverage
    - Identification of target UEs under weak uplink coverage
    - Uplink-coverage-based inter-frequency handover



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# Contents

## 2. Optional Features







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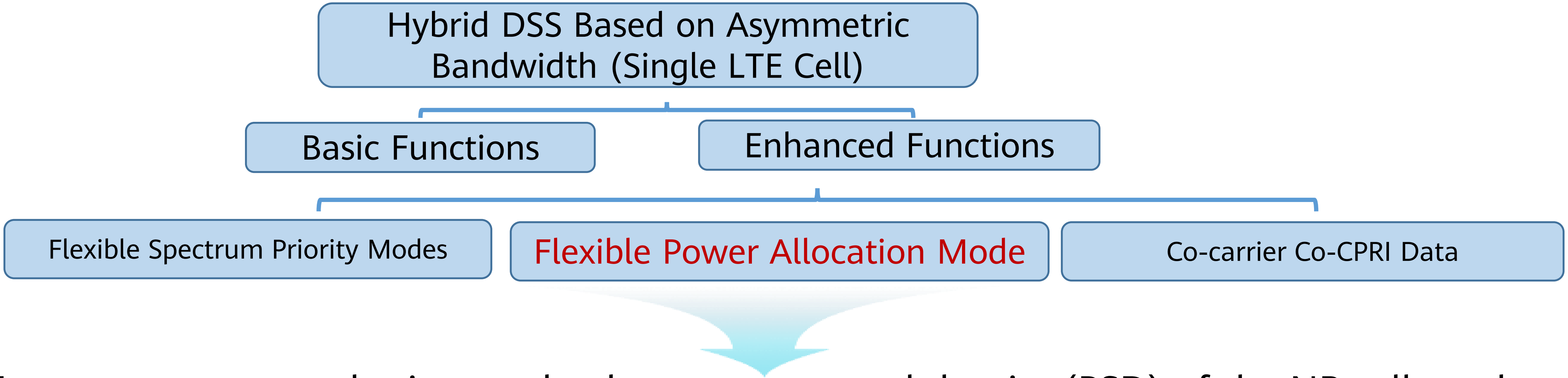
# Support for PSD Adaptation for NR Cells




- In spectrum power sharing mode, the power spectral density (PSD) of the NR cell can be adaptively adjusted.
  - When the transmit power required by the NR cell exceeds the configured power, the gNodeB adaptively reduces the PSD of the NR cell to ensure that the NR cell can use more spectrum resources, improving the spectral efficiency of UEs in the NR cell.
  - After this function is enabled, the gNodeB adaptively adjusts the PSD of data channels to improve the spectral efficiency of UEs in the NR cell.



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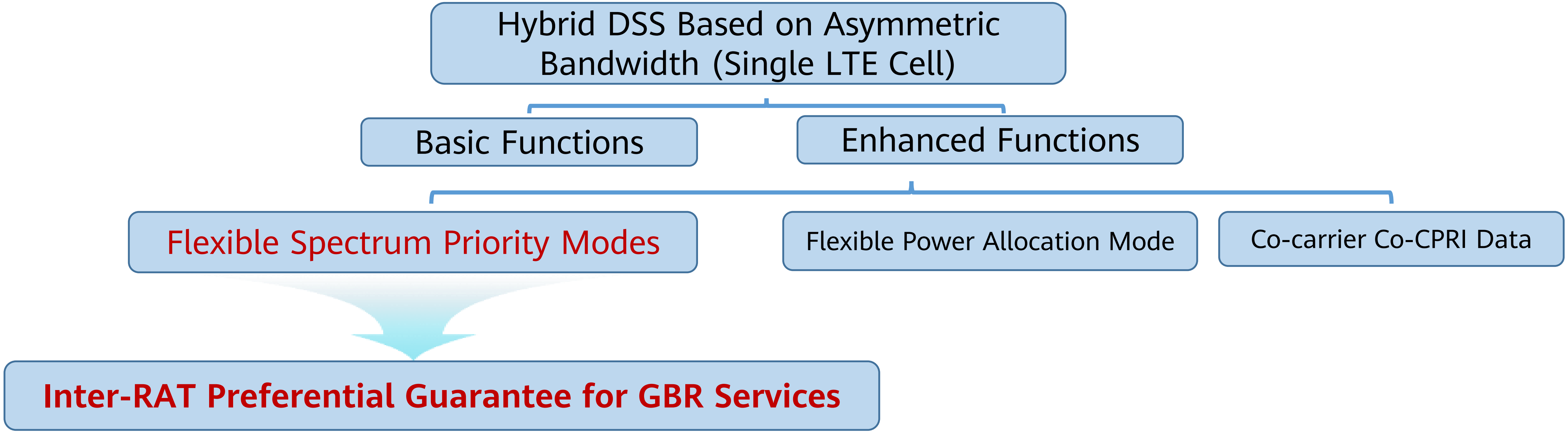
# Inter-RAT Preferential Guarantee for GBR Services

- The location of this enhanced function.



# Support for Inter-RAT Preferential Guarantee for GBR Services

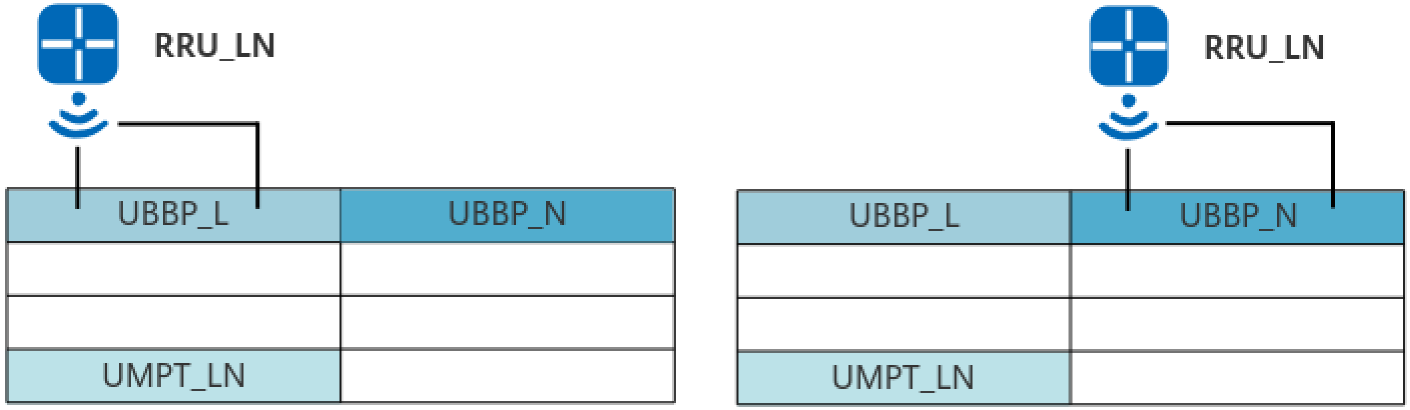
- If the percentage of resources preferentially allocated to a RAT is less than the percentage required by GBR services of that RAT, experience of GBR services of that RAT will be affected.
  - For example, if the percentage of resources preferentially allocated to LTE is 40% and the percentage required by GBR services is 60%, 20% of GBR service requirements cannot be satisfied, affecting GBR service experience.
- The inter-RAT preferential guarantee for GBR services, this function defines the **priority** of GBR services as follows:

| LTE GBR services | >= | NR non-GBR services | | NR GBR services | >= | LTE non-GBR services |
|---|---|---|---|---|---|---|

  - In the preceding example, the unsatisfied LTE GBR services can occupy the resources of NR non-GBR services. In this way, GBR service experience is preferentially guaranteed.

# Support for Intra-Board Cold Backup Ring Topology

- Intra-board cold backup ring topology in co-MPT LTE/NR scenarios:
  - LTE and NR share a BBU, and both the LTE and NR baseband processing units are connected directly to the RRU through an optical fiber to form a ring topology.




Intra-board cold backup ring topology in co-MPT LTE/NR scenarios

- LampSite base stations do not support the preceding networking.



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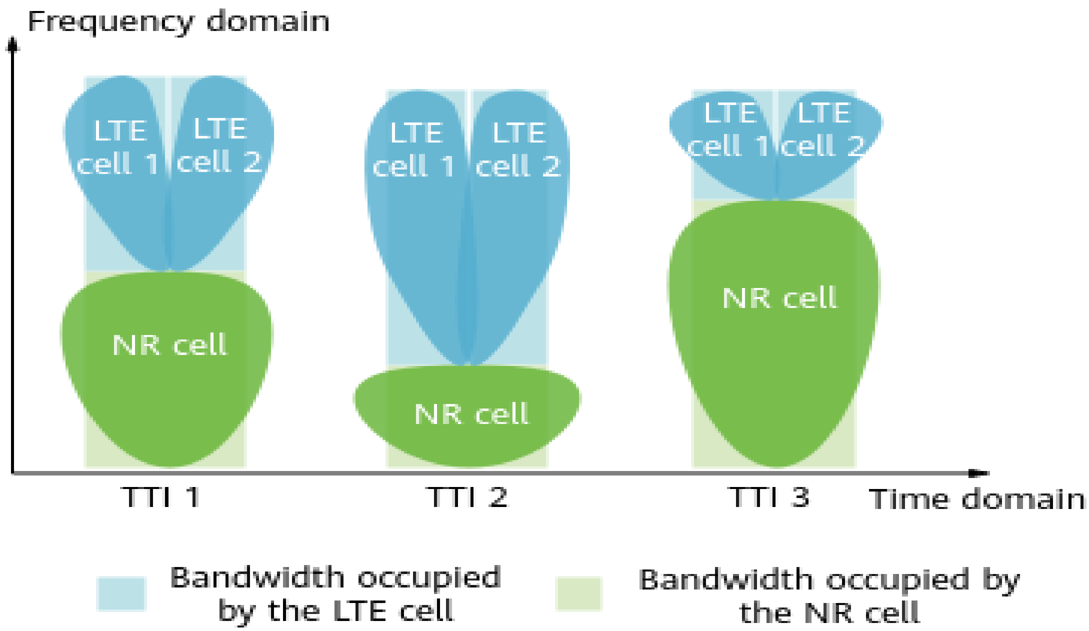
# Support for Hybrid DSS Based on Asymmetric Bandwidth (Multiple LTE Cells)

- This function enables the two to four LTE FDD sector split cells served by the beams generated by Static Multiple Beam in smart 8T8R mode and 32T32R massive MIMO mode (referred to as LTE cells) and an NR FDD cell (referred to as NR cell) to dynamically share time-frequency resources on a shared spectrum segment based on their traffic volumes.
    - LTE and NR cells in the associated spectrum sharing cell groups can share time-frequency resources on a shared spectrum segment.

Frequency domain

- Dynamic spectrum sharing is performed per RB.
- Spectrum resources are dynamically allocated to LTE and NR cells based on their traffic volumes.
- The traffic volumes in the LTE cells are the same.




Time domain

- Flash spectrum sharing is supported on a 1 ms basis, meaning spectrum resources can be coordinated and scheduled every 1 ms.

# Other Functional Enhancements

- The 25 MHz NR cell bandwidth is supported.
- 8T8R RRUs support Hybrid DSS Based on Asymmetric Bandwidth.
- 700 MHz RF modules now support Hybrid DSS Based on Asymmetric Bandwidth.
- supports the 32T32R TX/RX mode.
  - The 2.2:1 CPRI compression ratio is required in this TX/RX mode, so that CPRI compression can be used together with the co-carrier co-CPRI data function. LampSite base stations do not support this change.
- The feature application in common bandwidth scenarios is supported, including standard and non-standard bandwidth scenarios.

| LTE Cell Bandwidth (standard) | NR Cell Bandwidth (standard) |
|---|---|
| 10 MHz | 15 MHz |
| 10 MHz | 20 MHz |
| 15 MHz | 20 MHz |

| LTE Cell Bandwidth (non-standard) | NR Cell Bandwidth (non-standard) |
|---|---|
| 10 MHz | 14.8 MHz |
| 15 MHz | 19.6 MHz |
| 15 MHz | 19.8 MHz |

# Simplified Parameter Configurations for Hybrid DSS Based on Asymmetric Bandwidth

- The parameter configurations for Hybrid DSS Based on Asymmetric Bandwidth have been simplified by deleting the **LTE_SS_PBCH_RM_SW** and **ZP_TRS_AVOIDANCE_MODE_SW** options from the **NRDUCellAlgoSwitch.SpectrumCloudEnhSwitch** parameter.
- In upgrade scenarios, if these options are deselected before the upgrade, the downlink throughput of the NR cell increases after the upgrade.



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# Q&A

1. Which of the following description about Hybrid DSS Based on Asymmetric Bandwidth (Multiple LTE Cells) is correct?

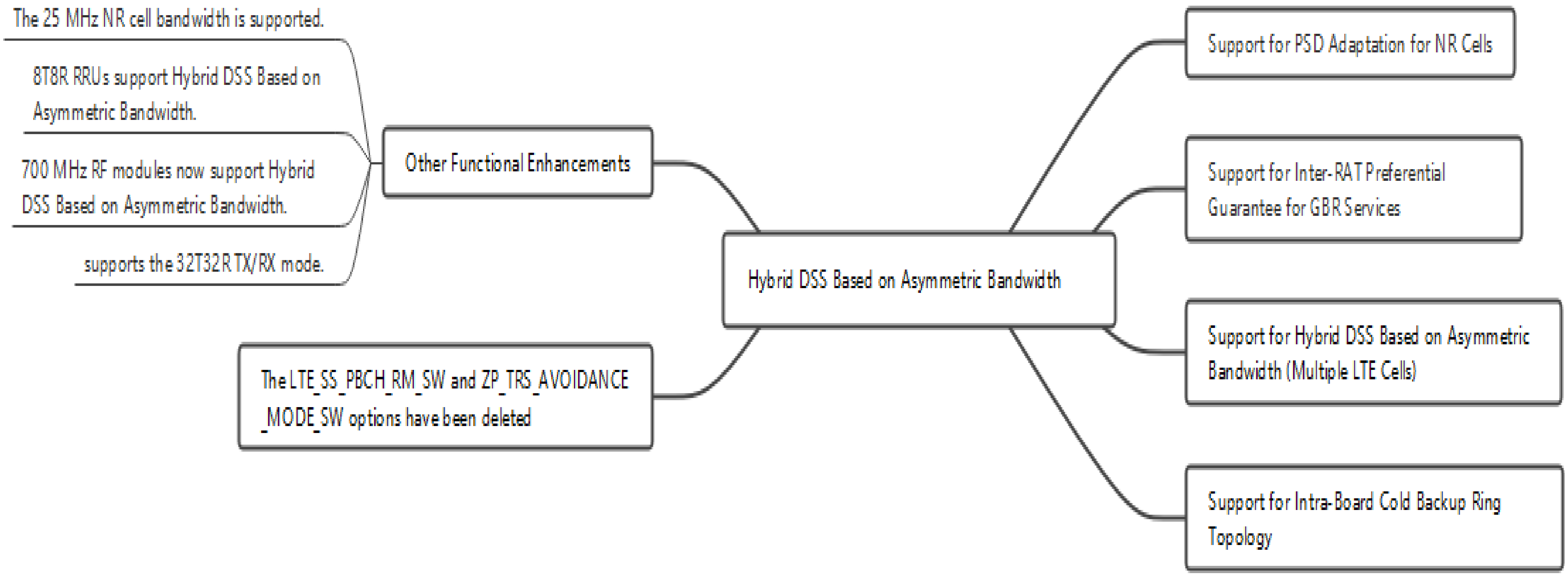
A. Dynamic spectrum sharing is performed per RBG.

B. Flash spectrum sharing is supported on a radio frame basis.

C. The LTE cells can use the smart 8T8R mode and 32T32R massive MIMO mode.

D. All types of 8T8R RRUs support this function.

# Section Summary



# Contents

## 2. Optional Features







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# The Background of Virtual Grid-based Multi-Frequency Coordination

- On multi-frequency networks, inter-frequency handovers or carrier selection usually needs to be performed for UEs to provide optimal user experience.
  - Inter-frequency handovers depend on inter-frequency measurements, which decrease UE throughput.
  - When a base station selects carriers for a UE, the base station determines whether to change the carriers for the UE mainly based on the RSRP reported by the UE. In this case, the carriers selected may not be able to provide optimal user experience.
- Virtual grid models can be used to predict inter-frequency RSRP and downlink intra-frequency spectral efficiency.

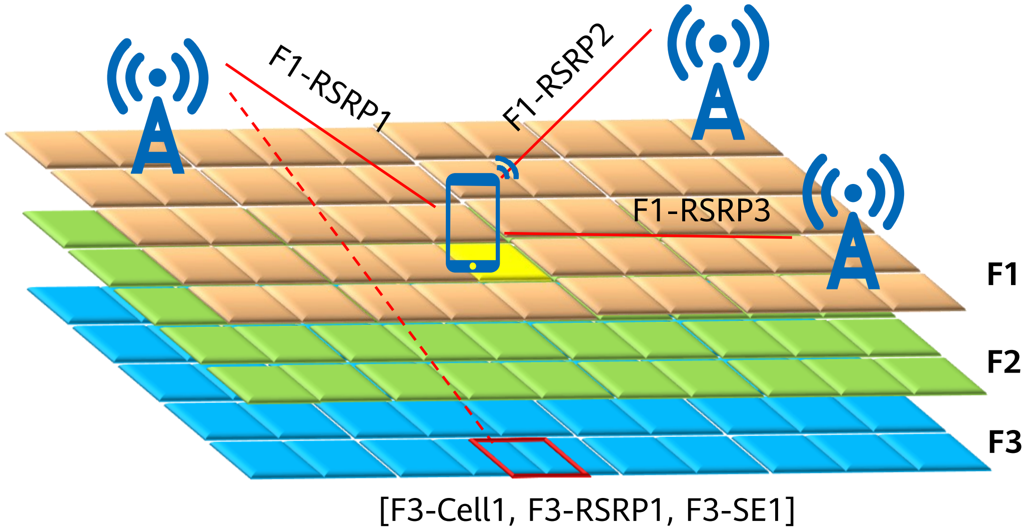
The predicted RSRP and spectral efficiency are used for inter-frequency handovers and experience-based smart carrier selection with in the NR system

RSRP prediction model

Downlink intra-frequency spectral efficiency prediction model

# What is a Virtual Grid Model?

- Virtual grid model
  - The mapping f(x) is obtained using a machine learning algorithm.
  - The mapping f(x) is contained in an entity called a virtual grid model.
  - Virtual grid models include RSRP prediction models and downlink intra-frequency spectral efficiency prediction models.




Virtual grid information:
[(F1-Cell1, F1-RSRP1), (F1-Cell2, F1-RSRP2), ...]

+

Inter-frequency radio signal characteristics:
[F3-Cell1, F3-RSRP1, F3-SE1]

Input → Machine learning algorithm → Output

**Virtual grid model**:
Inter-frequency radio signal characteristics, for example:
[F3-Cell1, F3-RSRP1, F3-SE1] = **f**([(F1-Cell1, F1-RSRP1), (F1-Cell2, F1-RSRP2), ...], Ncell Load of F3-Cell1, UE Capability)

# Virtual Grid Model

The gNodeB obtains the virtual grid information about a UE on a frequency.

gNodeB queries

RSRP prediction models

To quickly predict the RSRP of the UE on this neighboring frequency.

The prediction result can be used for coverage-, service-, uplink-interference-, and frequency-priority-based inter-frequency handovers, and SCell configuration for CA.

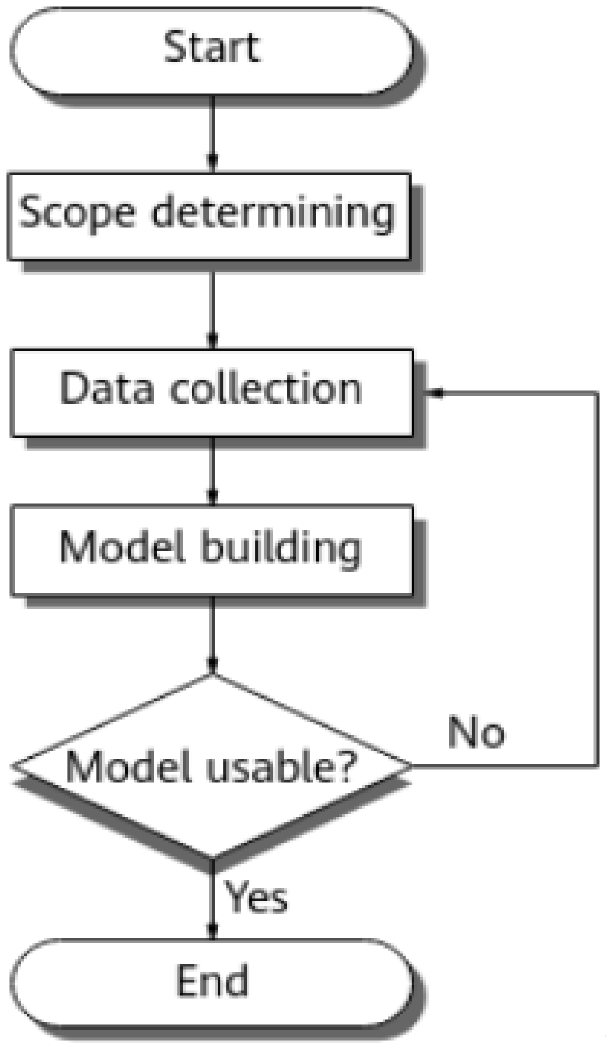
Downlink intra-frequency spectral efficiency prediction models

To quickly predict the spectral efficiency of the UE on this frequency

The prediction result can be used for experience-based smart carrier selection.

# Virtual Grid Model Building

- Process of building virtual grid models
  1. The gNodeB determines the scope of cells and frequencies for which virtual grid models are to be built.
  2. The gNodeB randomly selects 15 UEs in individual cells every 40s and collects their measurement reports on different frequencies as sample data for RSRP prediction model training.
  3. The gNodeB starts model training and then calculates the model accuracy.
  4. The gNodeB evaluates whether each model can be used based on its model accuracy.
  5. After a model is built for a cell, the gNodeB randomly selects three UEs in the cell every 40s. It collects sample data from the three UEs over seven days to build a new model. If the new model is more accurate than the previous model, the new one is used.



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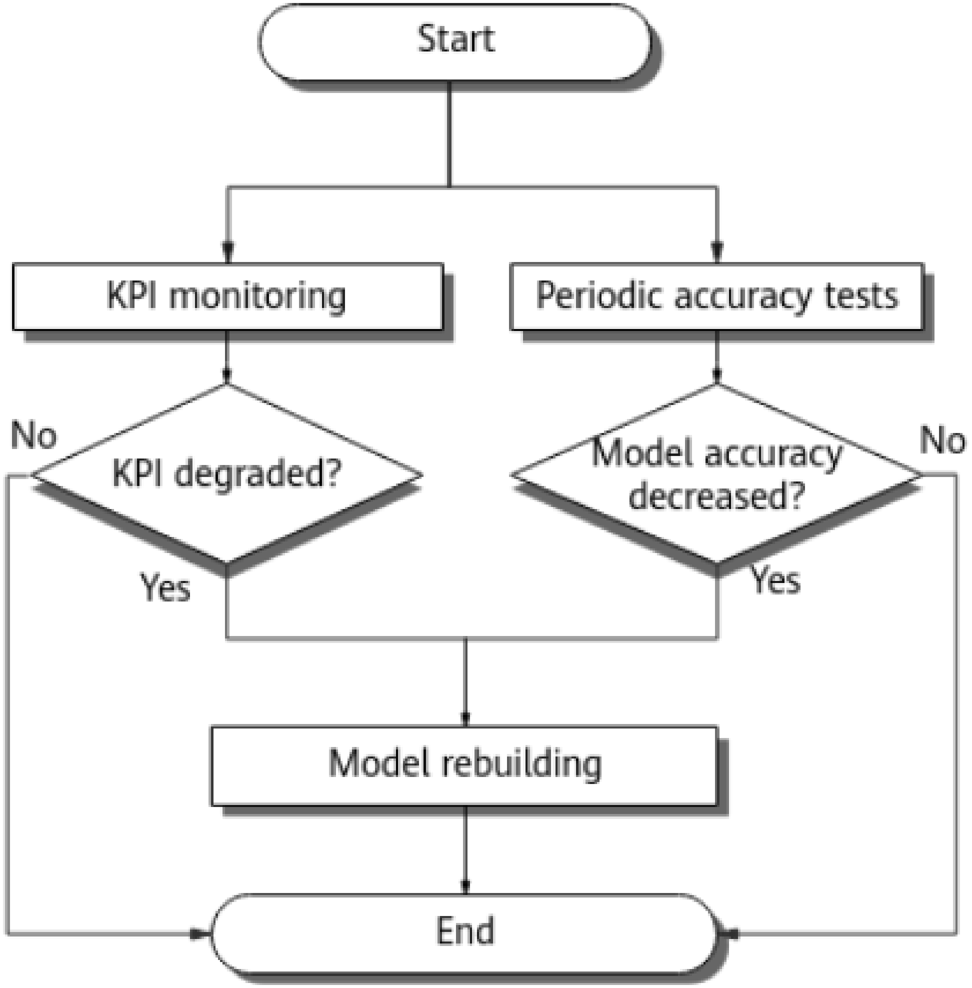
# Virtual Grid Model Update

- Process of monitoring the performance of virtual grid models and updating models
  - After RSRP prediction models are built, the gNodeB monitors their performance and updates them as shown in the figure on the fight.
  - For downlink intra-frequency spectral efficiency prediction models, model rebuilding is triggered only by periodic model accuracy tests. The accuracy tests and model accuracy decrease decision are performed in the same way as they are performed for RSRP prediction models.



# Virtual Grid Model Maintenance

- Suspension of model building and use

| Virtual Grid | Parameter for Function Disabling | Description |
|---|---|---|
| RSRP prediction model | **NR_IF_HO_MEAS_QTY_PRED_FUN_SW** option of the **NRCellSmartMultiCarr**.NrMultiCarrierAlgoSwitch parameter | The gNodeB stops the building and use of virtual grid models and saves the models that have been successfully built.<br>These models can be stored for a maximum of seven days as long as the gNodeB is not reset. If the option is selected again within seven days, the gNodeB considers the models to be usable. |
| Downlink intra-frequency spectral efficiency prediction model | **DL_INTRA_FREQ_SPCT_EFF_PRED_SW** option of the **NRCellSmartMultiCarr**.NrMultiCarrierAlgoSwitch parameter | |

- Model deletion

| Virtual Grid | Parameter for Function Disabling | Description |
|---|---|---|
| RSRP prediction model | **VG_MODEL_ALLOW_BUILD_FLAG** option of the **NRCellFreqRelation**.AggregationAttribute parameter | The gNodeB will delete the downlink intra-frequency spectral efficiency prediction models of the local cell to release the occupied specifications. |
| Downlink intra-frequency spectral efficiency prediction model | **DL_INTRAF_SE_MODEL_BUILD_ALLOW** option of the **NRCellSmartMultiCarr**.ModelBuildingSwitch parameter | |

# Use of Virtual Grid Models

- Use of RSRP prediction models in inter-frequency handovers within the NR system
  - If the RSRP (predicted using the related virtual grid model) of the strongest inter-frequency neighboring cell on a frequency meets a specific requirement, the gNodeB considers this inter-frequency cell as a candidate for an inter-frequency handover.
  - If the predicted RSRP of the strongest inter-frequency neighboring cell on a frequency does not meet a specific requirement, the gNodeB filters out measurements of this frequency and checks the next neighboring frequency. Finally, the gNodeB selects the cell with the highest RSRP among all candidate cells as the target cell for the inter-frequency handover.

| Inter-Frequency Handover | Option of the NRCellAlgoSwitch.AiInterFreqHoOptSwitch Parameter |
|---|---|
| Coverage-based inter-frequency handover | COV_IF_HO_MEAS_QTY_PRED_SW |
| Service-based inter-frequency handover | SERV_IF_HO_MEAS_QTY_PRED_SW |
| Uplink-interference-based inter-frequency handover | ULINTRF_IF_HO_MEAS_QTY_PRED_SW |
| Frequency-priority-based inter-frequency handover | FRQ_PRI_IF_HO_MEAS_QTY_PRED_SW |

# Use of Virtual Grid Models (Cont.)

- Use of RSRP prediction models in SCell configuration for CA
  - Intra-NR SCell configuration for CA uses the RSRP prediction results of virtual grid models when the **SCC_MEAS_QTY_PRED_SW** option of the **NRCellCaMgmtConfig**.CaStrategySwitch parameter is selected.
  - If the RSRP (predicted using the related virtual grid model) of the strongest inter-frequency neighboring cell on a frequency is greater than or equal to the **threshold**, the gNodeB considers this inter-frequency cell as a candidate SCell for CA.
  - If the predicted RSRP of the strongest inter-frequency neighboring cell on a frequency is less than the **threshold**, the gNodeB filters out the measurements of this frequency and checks the next neighboring frequency. Finally, the gNodeB selects the cell with the highest RSRP among all candidate SCells and adds this cell as an SCell for CA.





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# Specifications of Virtual Grid Models

- The main control board must be a UMPTg, UMPTga, or UMPTe. The virtual grid model specifications supported by each type of main control board working in different modes are as follows.

| Main Control Board | Working Mode | NR Inter-Frequency RSRP Prediction Model Specifications | NR Downlink Intra-Frequency Spectral Efficiency Grid Model Specifications |
|---|---|---|---|
| UMPTg | NR-only | 36 | 30 |
| | Co-MPT multiple modes | 36 | 30 |
| UMPTga | NR-only | 36 | 30 |
| | Co-MPT multiple modes | 18 | 15 |
| UMPTe | NR-only | 36 | 30 |
| | Co-MPT multiple modes | 0 | 0 |

Note: UMPTe series main control boards working in co-MPT multiple modes do not support virtual grid models.

# Benefits

- The Virtual Grid-based Multi-Frequency Coordination feature allows for the skipping of inter-frequency measurements, thereby increasing the average downlink UE throughput (indicated by **User Downlink Average Throughput (DU)**) by up to 5%.
- The larger the average number of inter-frequency handovers (indicated by **N.HO.InterFreq.Coverage.PrepAttOut** and **N.HO.InterRAT.N2E.Coverage.PrepAttOut**) and the number of SCell configuration attempts (indicated by **N.CA.SCell.Add.Att**) before feature activation, the more significant the feature gains.

# Impacts

- The gNodeB needs to select a certain number of UEs for virtual grid model building and update. The selected UEs will perform gap-assisted inter-frequency measurements, which decrease the average downlink throughput and average uplink throughput of these UEs.
- The CPU usage of the main control board increases because of frequent virtual grid model query.
- Periodic A3 measurements increase the number of signaling messages over the air interface, which increases signaling radio bearer (SRB) traffic accordingly.
- The average MCS index may decrease because SRBs use MCSs with small indexes. In addition, the transmission of RRC connection reconfiguration messages may fail and therefore the service drop rate may increase.

# Software requirements

- Before enabling this function, ensure that the following mutually exclusive functions have been disabled.

| RAT | Function | Function Switch |
|---|---|---|
| FDD<br>Low-frequency TDD | Hyper Cell | **NRDUCell**.NrDuCellNetworkingMode parameter set to **HYPER_CELL** |
| FDD<br>Low-frequency TDD | Cell Combination | **NRDUCell**.NrDuCellNetworkingMode parameter set to **HYPER_CELL_COMBINE_MOD** |
| FDD<br>Low-frequency TDD | High-speed Railway Superior Experience | **NRDUCell**.HighSpeedFlag parameter set to **HIGH_SPEED** |

# Hardware Requirements

- Base station models
  - 3900 series base stations and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.
  - DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.
- Boards
  - The main control board must be a UMPTg, UMPTga, or UMPTe.
  - There are no requirements for BBPs.
- Licenses

| RAT | Feature ID | Feature Name | Model | Sales Unit |
|---|---|---|---|---|
| FDD/low-frequency TDD | FOFD-060201 | Virtual Grid-based Multi-Frequency Coordination | NR0S00VGMC00 | Per Cell |



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# Activation Command Examples

//Enabling virtual grid model building

MOD NRCELLFREQRELATION: NrCellId=0, SsbFreqPos=7853, AggregationAttribute=VG_MODEL_ALLOW_BUILD_FLAG-1;

//Enabling measurement quantity prediction for intra-NR inter-frequency handovers

MOD NRCELLSMARTMULTICARR: NrCellId=0, NrMultiCarrierAlgoSwitch=NR_IF_HO_MEAS_QTY_PRED_FUN_SW-1;

//Enabling the building of downlink intra-frequency spectral efficiency models

MOD NRCELLSMARTMULTICARR: NrCellId=0, ModelBuildingSwitch=DL_INTRAF_SE_MODEL_BUILD_ALLOW-1;

//Enabling downlink intra-frequency spectral efficiency prediction

MOD NRCELLSMARTMULTICARR: NrCellId=0, NrMultiCarrierAlgoSwitch=DL_INTRA_FREQ_SPCT_EFF_PRED_SW-1;

//Enabling AI-based inter-frequency handover optimization, **MOD NRCELLALGOSWITCH** is a high-risk command.

MOD NRCELLALGOSWITCH: NrCellId=0, AiInterFreqHoOptSwitch=COV_IF_HO_MEAS_QTY_PRED_SW-1&SERV_IF_HO_MEAS_QTY_PRED_SW-1&ULINTRF_IF_HO_MEAS_QTY_PRED_SW-1&FRQ_PRI_IF_HO_MEAS_QTY_PRED_SW-1;

//Enabling SCC measurement prediction

MOD NRCELLCAMGMTCONFIG: NrCellId=0, CaStrategySwitch=SCC_MEAS_QTY_PRED_SW-1;





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# Deactivation Command Examples

//Disabling AI-based inter-frequency handover optimization, **MOD NRCELLALGOSWITCH** is a high-risk command.

MOD NRCELLALGOSWITCH: NrCellId=0, AiInterFreqHoOptSwitch=COV_IF_HO_MEAS_QTY_PRED_SW-0&SERV_IF_HO_MEAS_QTY_PRED_SW-0&ULINTRF_IF_HO_MEAS_QTY_PRED_SW-0&FRQ_PRI_IF_HO_MEAS_QTY_PRED_SW-0;

//Disabling the use of virtual grid models for SCell configuration

MOD NRCELLCAMGMTCONFIG: NrCellId=0, CaStrategySwitch=SCC_MEAS_QTY_PRED_SW-0;

//Disabling measurement quantity prediction for intra-NR inter-frequency handovers

MOD NRCELLSMARTMULTICARR: NrCellId=0, NrMultiCarrierAlgoSwitch=NR_IF_HO_MEAS_QTY_PRED_FUN_SW-0;

//Disabling downlink intra-frequency spectral efficiency prediction

MOD NRCELLSMARTMULTICARR: NrCellId=0, NrMultiCarrierAlgoSwitch=DL_INTRA_FREQ_SPCT_EFF_PRED_SW-0;

//Disabling the building of downlink intra-frequency spectral efficiency models

MOD NRCELLSMARTMULTICARR: NrCellId=0, ModelBuildingSwitch=DL_INTRAF_SE_MODEL_BUILD_ALLOW-0;

//Disabling virtual grid model building

MOD NRCELLFREQRELATION: NrCellId=0, SsbFreqPos=7853, AggregationAttribute=VG_MODEL_ALLOW_BUILD_FLAG-0;





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# Observation of Virtual Grid Model Building

- Using MML commands
  - Run the **DSP NRCELLAIGRIDMODEL** command to query the status of virtual grid models in a cell.
    - If **RSRP Forecast Status is Available**, the RSRP prediction model has been successfully built.
    - If the value of **Intra-Freq Spct Efficiency Model Status is Available**, the downlink intra-frequency spectral efficiency prediction model has been successfully built.
- Using counters
  - RSRP prediction models can be observed using the **N.NrVirtualGrid.Model.Avg** counter. If the value of this counter is not 0, RSRP prediction models have been successfully built.

# Observation of the Use of Virtual Grid Models

- Observe the following counters. If the value of any counter is greater than 0, RSRP prediction models have been used.

| Counter ID | Counter Name |
|---|---|
| 1911831557 | N.HO.NrVirtualGrid.Model.ExecAttOut |
| 1911831556 | N.HO.NrVirtualGrid.Model.ExecSuccOut |
| 1911831558 | N.HO.NrVirtualGrid.Model.PrepAttOut |
| 1911831564 | N.CA.SCell.VirtualGrid.Add.Succ |
| 1911831565 | N.CA.SCell.VirtualGrid.Add.Att |
| 1911831567 | N.NrVirtualGrid.Model.InterFreq.MeasFree.Times |
| 1911831619 | N.NsaDc.NrVirtualGrid.Model.PSCell.Change.Att |
| 1911831620 | N.NsaDc.NrVirtualGrid.Model.PSCell.Change.Succ |

- Observe the value of **User Downlink Average Throughput** (DU) to check the increase in UE throughput after this feature is enabled.

# Q&A

1. Which of the following functions can benefit from virtual-grid-based inter-frequency handover optimization? (    )

   A. Coverage-based inter-frequency handover

   B. Service-based inter-frequency handover

   C. SSB SINR-based inter-frequency handover

   D. Uplink-interference-based inter-frequency handover

   E. Frequency-priority-based inter-frequency handover

# Section Summary

- Virtual grid models can be used to predict inter-frequency RSRP and downlink intra-frequency spectral efficiency.
- The predicted RSRP and spectral efficiency are used for inter-frequency handovers and experience-based smart carrier selection with in the NR system, respectively, to improve user experience.

# Contents

## 2. Optional Features







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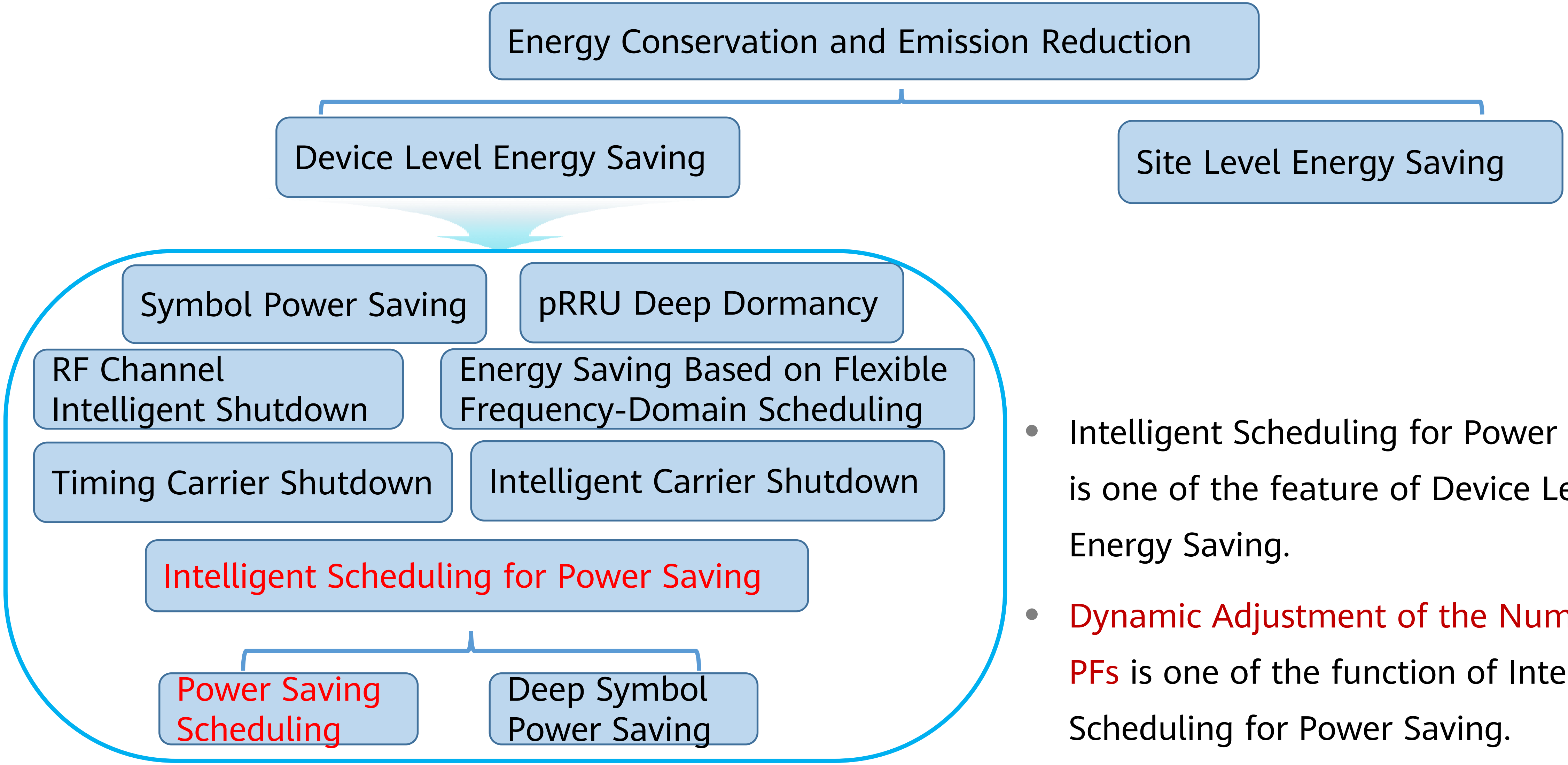
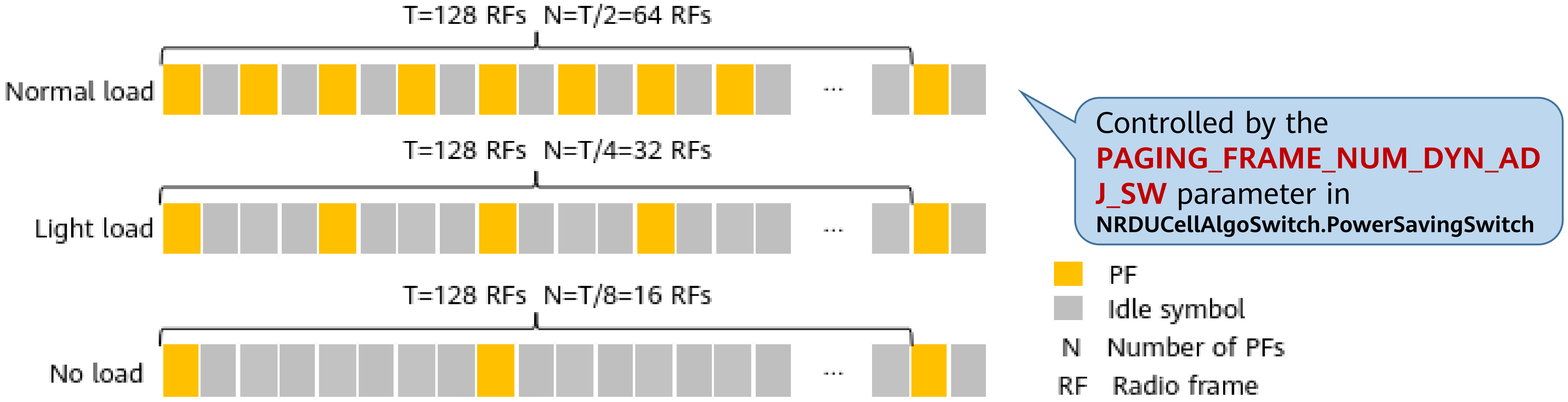
# The Location of the Enhanced Feature




- Intelligent Scheduling for Power Saving is one of the feature of Device Level Energy Saving.
- Dynamic Adjustment of the Number of PFs is one of the function of Intelligent Scheduling for Power Saving.

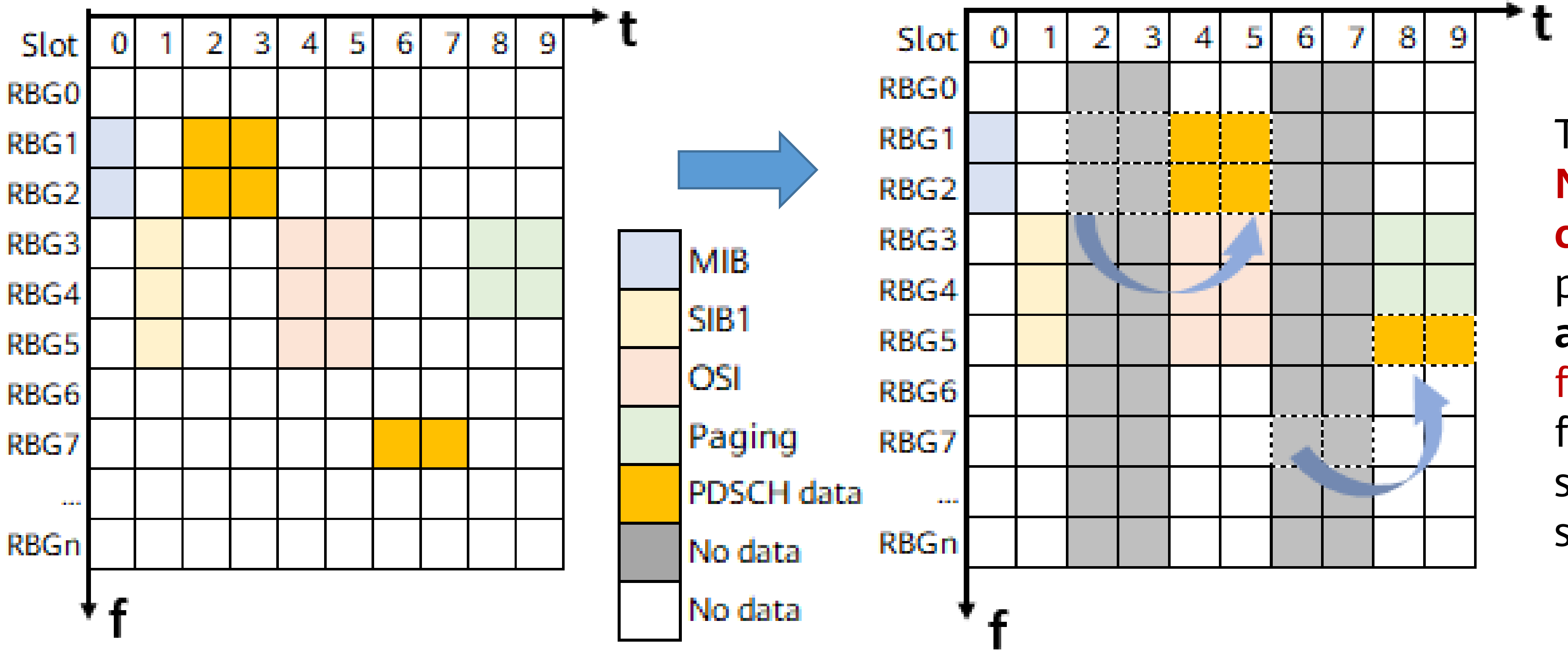
# Dynamic Adjustment of the Number of PFs

- When the base station detects that the network is under light or no load, it reduces the number of PFs sent within a paging cycle (referred to as T) to increase the number of symbols with no data transmission.
- When the base station detects that the network load is normal, it restores the number of PFs sent within T. Dynamic adjustment of the number of PFs does not take effect by default.



# Data Convergence in Slots

- The base station converges and sends PDSCH data in the slots corresponding to the MIB, SIB1, OSI, or paging. This concentrates PDSCH data scheduling in the time domain and increases the number of symbols with no data transmission. This process also increases the scheduling delay to a certain extent.




Data Convergence in Slots

The **NRDUCellPowerSaving.RlcFirstPktDelayThld** parameter **has been added** to indicate the RLC first packet delay threshold for data convergence in slots in power saving scheduling.

# Parameter Control over the Triggering Evaluation Period for Power Saving Scheduling

- Uses the existing parameter **NRDUCellPowerSaving.ShutdownTrigJudgePeriod**, which specifies the triggering evaluation period indicated by an energy saving policy index. Entry into or exit from power saving scheduling is triggered for a cell if this cell meets entering or exiting conditions in the period specified by this parameter.
- Within the configured range of time in which power saving scheduling can take effect, a cell periodically checks whether the downlink PRB usage is less than or equal to the downlink PRB usage threshold for starting power saving scheduling in the cell in the specified triggering evaluation period.
- If the condition is met, the cell automatically enters the power saving scheduling state.

# Parameter Control over the Triggering Evaluation Period for Power Saving Scheduling (Cont.)

- After the cell enters the power saving scheduling state, it periodically checks whether the following conditions are met in the specified triggering evaluation period. If one of the conditions is met, the cell automatically exits this state.
  - The current time is not within the range of time in which power saving scheduling can take effect. This period is determined by the **NRDUCellPowerSaving.StartTime** and **NRDUCellPowerSaving.StopTime** parameters.
  - The downlink PRB usage of the cell is greater than the sum of the **NRDUCellPowerSaving.DlPrbThld** and **NRDUCellPowerSaving.DlPrbOffset** parameter values.

For an upgrade from a version earlier than V100R018C10 to V100R018C10 or later, if **the NRDUCellPowerSaving.PowerSavingType** parameter is set to **POWER_SAVING_SCHEDULE** before the upgrade, the value of the **NRDUCellPowerSaving.DlPrbOffset** parameter will be 5 after the upgrade; otherwise, the **NRDUCellPowerSaving.DlPrbOffset** parameter will inherit its pre-upgrade value.

# Other Optimization

- The mutually exclusive relationships between power saving scheduling and Hyper Cell/Joint Transmission Cell Combination have been removed. Power saving scheduling can be enabled for hyper cells or combined cells in joint transmission mode.
  - This change applies to macro base stations, but not LampSite base stations.

# Optimized the Configurations

| Parameter ID | Description |
|---|---|
| NRDUCellPowerSaving.RlcFirstPktDelayThld | This parameter has been added to specify the RLC first packet delay threshold for data convergence in slots in power saving scheduling. |
| NRDUCellAlgoSwitch.PowerSavingSwitch | **RSVDSWPARAM0_BIT14** of this reserved parameter has been added to the disuse list. The **PAGING_FRAME_NUM_DYN_ADJ_SW** option has been added to specify whether to enable dynamic adjustment of the number of PFs in power saving scheduling.<br>Dynamic adjustment of the number of PFs takes effect only when both the **POWER_SAVING_SCHEDULE_SW** and **PAGING_FRAME_NUM_DYN_ADJ_SW** options of the **NRDUCellAlgoSwitch.PowerSavingSwitch** parameter are selected. |
| NRDUCellRsvdExt02.RsvdSwParam0 | **RSVDSWPARAM0_BIT26** of this reserved parameter has been added to the disuse list. Data convergence in symbols takes effect by default after power saving scheduling is enabled.<br>**RSVDSWPARAM0_BIT27** of this reserved parameter has been added to the disuse list. Data convergence in slots takes effect by default after power saving scheduling is enabled. |



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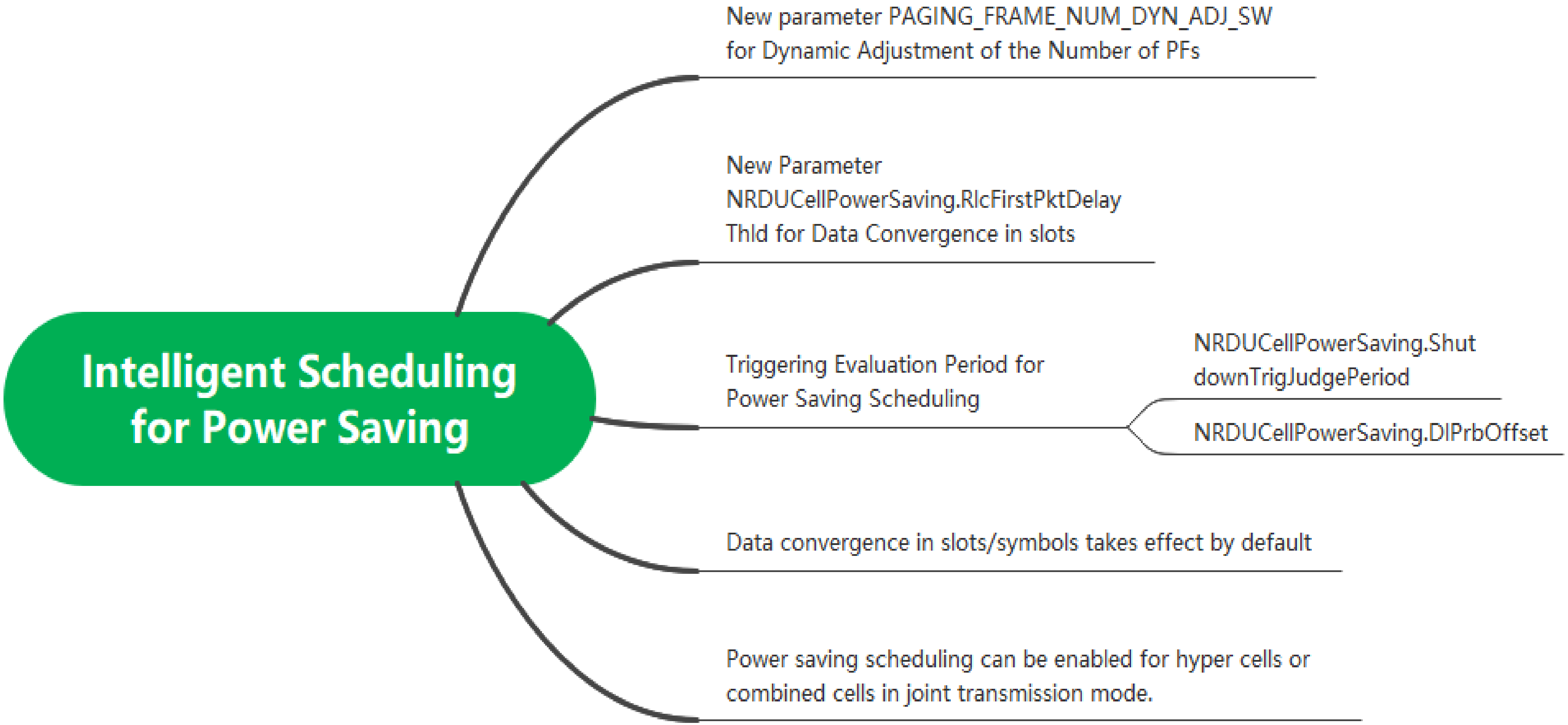
# Section Summary



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# Contents

## 2. Optional Features







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# Support for Configuration Reliability Protection During Deep Dormancy

- This function protects license reliability, configuration reliability, and reliability in fault scenarios during deep dormancy.
- If configurations are delivered during the RF module deep dormancy period, the following issues may occur:
  - The dynamic verification before configurations are imported into the database becomes invalid, and therefore the configuration data accuracy cannot be ensured.
  - The alarms generated when the configuration data fails to take effect cannot be reported in time.
- With the configuration reliability protection during deep dormancy function, the base station is woken up and deep dormancy pending is triggered before or during configuration delivery.
  - In this case, the dynamic verification can be performed before configurations are imported into the database, and the alarms generated when the configurations fail to take effect can be reported in time.



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# Configuration Reliability Protection During Deep Dormancy Requirements

- Configuration reliability protection during deep dormancy requires coordination between the OSS and NEs. This requires that the OSS and NEs be upgraded to the following versions supporting this function:
  - MAE-Access V100R021C10SPC260 or later
  - MAE-Deployment V100R021C10SPC260 or later

# Impacts of Configuration Reliability Protection During Deep Dormancy

- Impacts on the network
  - Assume that the batch processing tasks of the OSS contain gNodeBFunction or eNodeBFunction MML commands that affect cell setup or Node MML commands, and an NE of the base station is in the deep dormancy state. The OSS executes related configurations after the base station exits the deep dormancy state. This increases the waiting time before configuration execution.
  - Assume that an XML configuration file contains a gNodeBFunction or eNodeBFunction MML command that affects cell setup or a Node MML command (including a single power-related command), and an NE of the base station is in the deep dormancy state. The base station automatically exits the deep dormancy state and then executes the command.

# Optimized Design of RF Module Deep Dormancy in Fault Scenarios

- If the base station has a module fault or service fault that will cause cell unavailability or fault transfer after a module enters the deep dormancy state, the module will not enter this state.
- If the module is already in the deep dormancy state when the fault occurs, it will exit this state.
- Faults that affect the deep dormancy reliability include device faults, configuration conflicts, and resource conflicts.
  - When a device fault occurs on a module, this module does not enter the deep dormancy state.
  - When a service fault occurs, the modules of the entire base station do not enter the deep dormancy state. For a separate-MPT multimode base station, neither the local nor peer RAT enters the deep dormancy
- The deep dormancy function can be restored after the faults are rectified.

# Optimization of RF module deep dormancy

- NR sector split cells, hyper cells, and combined cells support RF module deep dormancy.
- Use **DSP BRDDORMANCY** to query the power saving status, and the reason for not entering the dormancy state has been added to the command output.

```
DSP BRDDORMANCY: QUERYTYPE=BOARD, CN=0, SRN=0, SN=3;
The result is shown as follows:
+++    0        2021-11-10 15:19:37
O&M    #39
%%DSP BRDDORMANCY: QUERYTYPE=BOARD, CN=0, SRN=0, SN=3;%%
RETCODE = 0  Operation succeeded.

Display BBU board power saving status
-------------------------------------
                     Cabinet No.  =  0
                     Subrack No.  =  0
                        Slot No.  =  3
         Baseband Shutdown State  =  Disable
            Board Dormancy State  =  Not in the Dormancy State
Reason for Not Entering Dormancy  =  Dormancy Capability Not Supported by the Hardware
Latest Board Dormancy Start Time  =  2021-11-09 14:01:31
 Latest Board Dormancy Stop Time  =  2021-11-09 14:07:31
(Number of results = 1)
```

# Section Summary

**RF Module Deep Dormancy (NR)**

- Support for Configuration Reliability Protection
- Optimized Design of RF Module Deep Dormancy in Fault Scenarios
- NR sector split cells, hyper cells, and combined cells support RF module deep dormancy.
- DSP BRDDORMANCY, display the reason for not entering the dormancy state.

# Contents

## 2. Optional Features

# Flexible Carrier Management (Only for High-Frequency Intra-Band CA)

- To reduce hardware resource consumption by CA UEs and increase the maximum allowed number of RRC_CONNECTED UEs on the network, flexible carrier management has been introduced.
- Flexible carrier management can be used in high-frequency intra-band CA. The principles are as follows:
  - Flexible carrier management is enabled when the **NRDUCellCarrMgmt.Fr2CaCarrMgmtPolicy** parameter is set to **USER_TRAFFIC_BASED**.
  - The gNodeB performs SCell configuration and removal as follows.



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# Flexible Carrier Management (Only for High-Frequency Intra-Band CA) (Cont.)

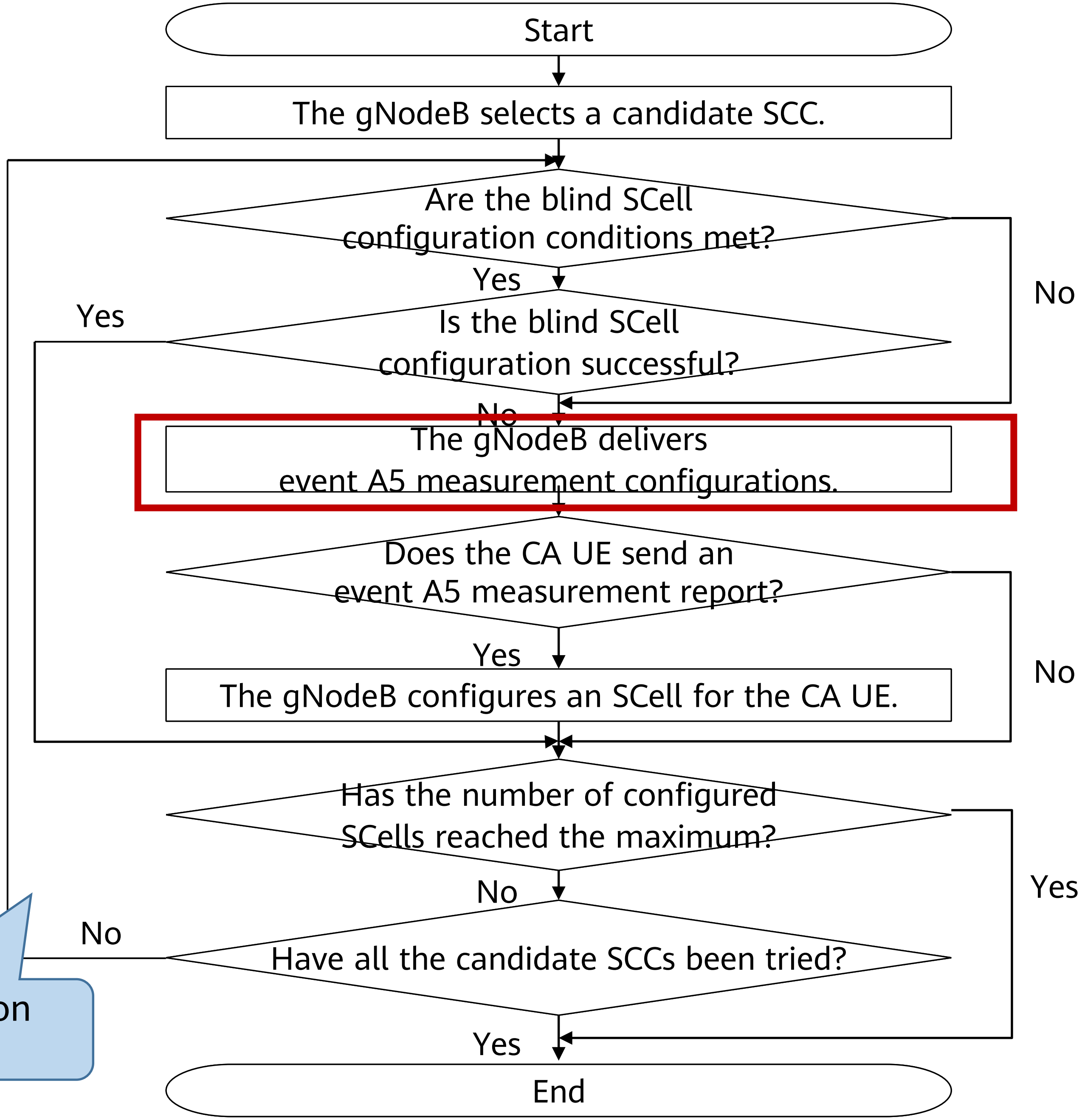
| Carrier Management Policy | Conditions | SCell Removal | SCell Configuration |
|---|---|---|---|
| Flexible carrier management | The number of hardware resource units consumed by RRC_CONNECTED UEs on a BBP or in a sector is higher than hardware resource threshold 1 | SCells are removed dynamically: An SCell is removed if it has been in the deactivated state for more than 5s.<br>SCells are removed if they become unavailable. | An SCell is configured for 2CC aggregation initially.<br>Then, the gNodeB checks every 100 ms whether the buffered traffic volume of the UE meets the conditions for traffic volume–triggered SCell activation. If the conditions are met three consecutive times, the gNodeB triggers SCell configuration until the number of successfully configured SCells reaches the maximum. |
| | The number of hardware resource units consumed by RRC_CONNECTED UEs on a BBP or in a sector is lower than hardware resource threshold 2 | SCells are removed if they become unavailable. | SCells are configured based on the capabilities of the UE and gNodeB. |

# Deployment of Flexible Carrier Management (for High Frequency Bands Only)

- Activation
  - //Enabling flexible carrier management for all high-frequency normal cells. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, Fr2CaCarrMgmtPolicy=USER_TRAFFIC_BASED;
- Network Impacts
  - //Disabling flexible carrier management for all high-frequency normal cells. *This command is a high-risk command.*
  - MOD NRDUCELLCARRMGMT: NrDuCellId=0, Fr2CaCarrMgmtPolicy=USER_EXP_BASED;
- Verification
  - Flexible carrier management has taken effect if the value of N.CA.SCell.Rmv.Att or N.CA.SCell.Rmv.Succ increases after this function is enabled.

# SCell Configuration

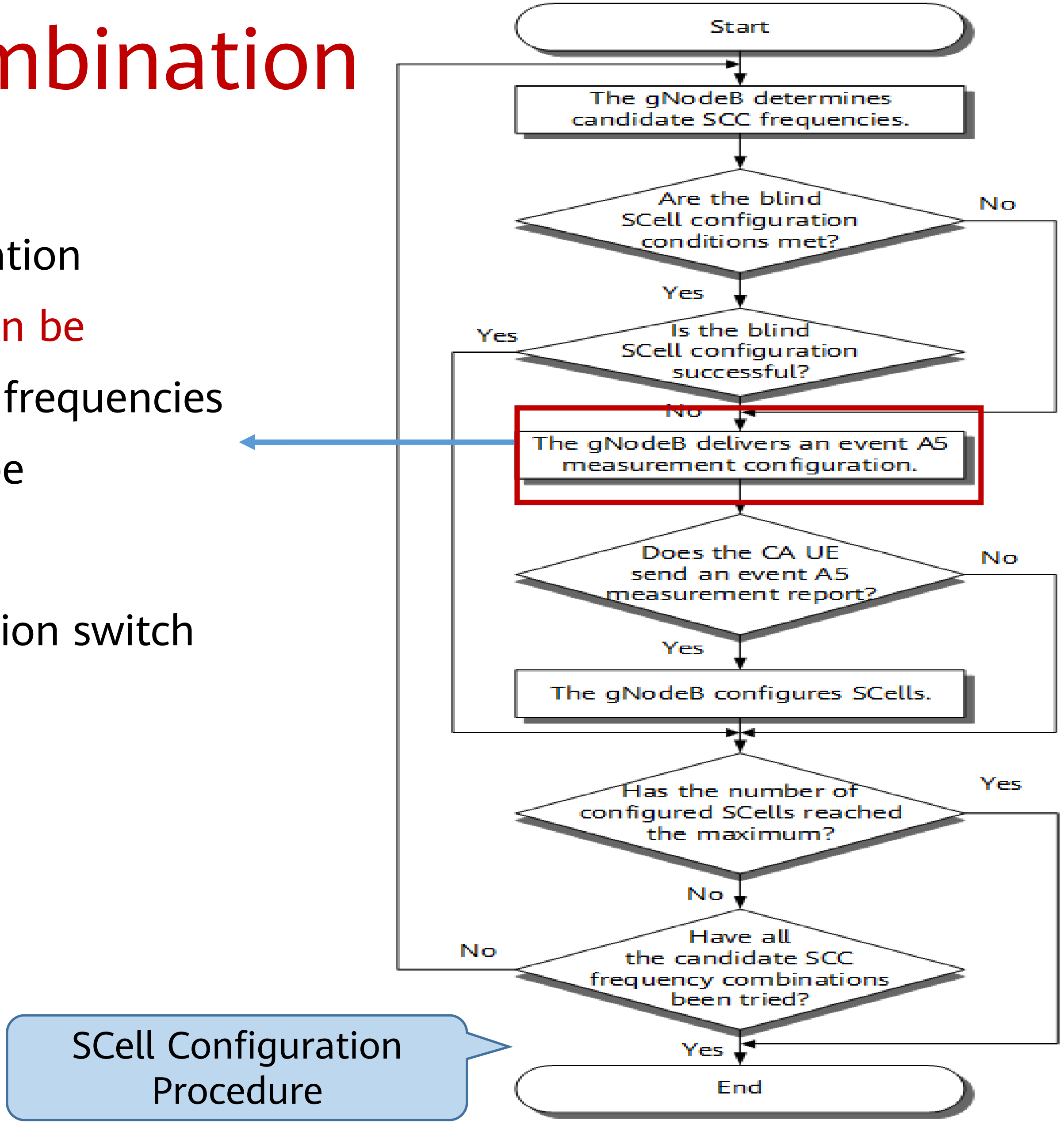
- During the Scell Configuration, the gNodeB sends an RRCReconfiguration message to configure cells on the candidate SCC frequencies as SCells.
- The optimal SCC frequency combination selection can be used to select the optimal SCC frequency combination for the UE.




SCell Configuration Procedure

# Optimal SCC Frequency Combination Selection

- With the function of optimal SCC frequency combination selection, the optimal SCC frequency combination can be selected for a UE when the number of an operator's frequencies is greater than the number of frequencies that can be aggregated for the UE.
- This function is controlled by the smart carrier selection switch (the SMART_CARR_SEL_SW option of the NRDUCellCollabServ.MultiCarrMgmtSw parameter).



# Service-based Optimal Carrier Selection

Scell Configuration in CA

- SCell Configuration
- SCell Change
- SCell Activation
- SCell Deactivation
- SCell Removal

Based on the service-aware carrier selection switch, gNodeB follows different policy to select the optimal SCC frequency combination for the UE.
If turned on, the gNodeB follows a policy of **Service-based Optimal Carrier Selection Policies**.

- In low-frequency scenarios, service-based optimal carrier selection is available. This function allows carrier selection policies to be changed flexibly based on UE traffic requirements given a specified CA capability combination selection policy. UEs therefore can achieve user-perceived rates that most fully meet their requirements.
- Service-based optimal carrier selection is controlled by the **SERVICE_AWARE_CARR_SEL_SW** option of the **NRDUCellCollabServ.MultiCarrMgmtSw** parameter.

# CA Early Data Split

- During the SCell Activation, the function of early data split has been added to downlink CA. This function is controlled by the **EARLY_SPLIT_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** parameter.

| Parameter | Status | Function |
|---|---|---|
| **EARLY_SPLIT_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** | Deselected | The SCell is considered to have been activated as long as it receives valid CQI reports, and then data can be distributed to the SCell. |
| | Selected | The SCell is considered to have been activated as long as it receives either valid CQI reports or valid reports for CSI-RS beam sweeping, and then data can be distributed to the SCell. |



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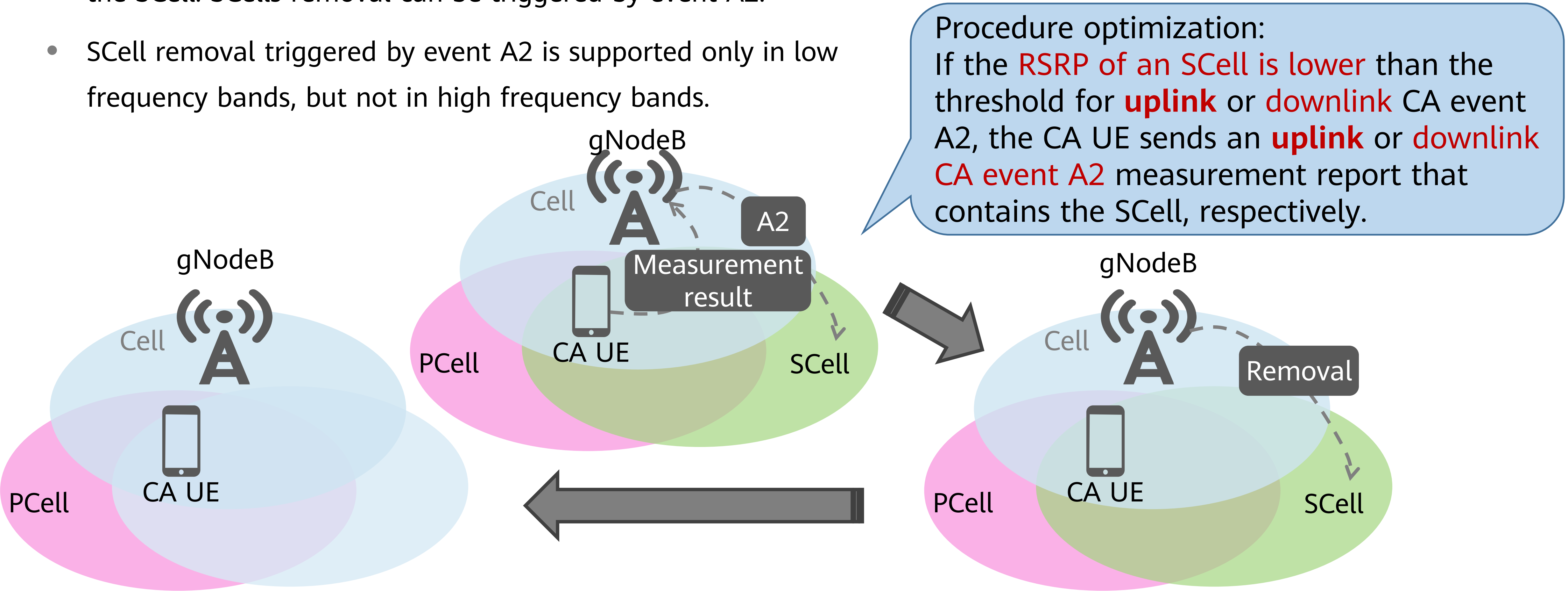
# Optimized SCell Removal

- If a CA UE reports event A2 for an SCell, the gNodeB removes the SCell. SCells removal can be triggered by event A2.
- SCell removal triggered by event A2 is supported only in low frequency bands, but not in high frequency bands.



# Support Uplink CA for NR FDD

- Uplink intra-band CA can be enabled by selecting the **INTRA_BAND_UL_CA_SW** option of the **NRDUCellAlgoSwitch.CaAlgoSwitch** parameter.
  - In NR FDD, uplink intra-band CA takes effect only when both the uplink intra-band CA switch and the FDD-only CA switch (the **FDD_FDD_CA_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** parameter) are turned on.
- With the Uplink intra-FR inter-band CA enabled, uplink inter-band SCell configuration is triggered. To enable uplink intra-FR inter-band CA between NR FDD cells, the **FDD_FDD_CA_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** parameter must also be selected.

# Trimmed Formal Parameters for CA

| In versions earlier than V100R018C10 | In V100R018C10 and later version |
| --- | --- |
| Downlink intra-band/inter-band CA in **NR FDD** is collectively controlled by the **INTRA_BAND_CA_SW/ INTRA_FR_INTER_BAND_CA_SW** option of the NRDUCellAlgoSwitch.CaAlgoSwitch parameter and the **FDD_FDD_CA_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** parameter. | the **FDD_FDD_CA_SW** option of the NRDUCellCarrMgmt.CaCompatibilitySwitch parameter **is deleted**. Therefore, in **NR FDD** as of this version, downlink intra-band/inter-band CA is enabled as long as the **INTRA_BAND_CA_SW/ INTRA_FR_INTER_BAND_CA_SW** option of the **NRDUCellAlgoSwitch.CaAlgoSwitch** parameter is selected. |
| Uplink intra-band/inter-band CA in **NR FDD** is collectively controlled by the **INTRA_BAND_UL_CA_SW/INTRA_FR_INTER_BAND_UL_CA_SW** option of the NRDUCellAlgoSwitch.CaAlgoSwitch parameter and the **FDD_FDD_CA_SW** option of the **NRDUCellCarrMgmt.CaCompatibilitySwitch** parameter. | Uplink inter-band CA is enabled as long as the **INTRA_BAND_UL_CA_SW/INTRA_FR_INTER_BAND_UL_CA_SW** option of the **NRDUCellAlgoSwitch.CaAlgoSwitch** parameter is selected. |
| TA command enhancement in CA is controlled by the **CA_TA_CMD_ENH_SW** option of the **NRDUCellCarrMgmt.CaEnhancedAlgoExtSwitch** parameter in low-frequency scenarios. | TA command enhancement in CA takes effect by default in low-frequency scenarios and **the option that used to control this function is deleted**. |



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# Extended the Range of Band+Bandwidth Combinations for CA

- Intra-FR inter-band/intra-band CA in low-frequency scenarios is now compatible with more band+bandwidth combinations. Below table provides the tables in 3GPP TS 38.101-1 V16.6.0 that list these combinations.

| CA Type | Table in Protocols |
| --- | --- |
| Intra-band CA | Table 5.5A.1-1 (for contiguous CA) and Table 5.5A.2-1 (for non-contiguous CA) in 3GPP TS 38.101-1 V16.6.0 |
| Intra-FR inter-band CA | Table 5.5A.3.1-1 (for 2CC aggregation) and Table 5.5A.3.2-1 (for 3CC aggregation) in 3GPP TS 38.101-1 V16.6.0 |
| Note 1: The preceding bandwidth combinations can be used only after cells with the specific bandwidths have been set up in the corresponding frequency bands.<br>Note 2: A CC can be configured for uplink CA only if it is also configured for downlink CA. | |

# CA PDCCH Capacity Optimization

- Assume that a UE receives an uplink grant and then a downlink grant in a single slot and sends HARQ feedback on the PUSCH. For certain such UEs, the downlink BLER increases.
- This issue can be prevented when the start symbol of the PDCCH is fixed at the first symbol available for the PDCCH in a cell for CA UEs that treat the cell as their PCell or SCell. However, PDCCH resources are selected less flexibly for CA UEs using this method. Data transmission for CA UEs may even be affected due to insufficient PDCCH resources in heavy-load scenarios.

- CA PDCCH capacity optimization is therefore introduced to improve data transmission for CA UEs in heavy-load scenarios. This function allows the start symbol of the PDCCH to be flexibly selected for CA UEs. In addition, the scheduling timing is optimized to prevent the downlink BLER from increasing. This function is controlled by the **CA_PDCCH_CAPACITY_OPT_SWITCH** option of the **NRDUCellCarrMgmt.CaEnhancedAlgoExtSwitch** parameter. This function is supported only in **low frequency bands**, not in high frequency bands.



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# Q&A

1. Which of the following description are incorrect?

A. In this version, NR FDD Cells do not support for Uplink Intra-FR Inter-Band CA.

B. Flexible carrier management can only be used in low-frequency intra-band CA.

C. The optimal SCC frequency combination selection function is used in SCell activation procedure.

D. CA PDCCH Capacity Optimization allows the start symbol of the PDCCH to be flexibly selected for CA UEs.

# Section Summary

- **CA**
  - **Intra-band CA**
    - Flexible Carrier Management (for High Frequency Bands Only)
  - **Intra-band CA && Intra-FR Inter-Band CA**
    - Optimal SCC Frequency Combination Selection in the SCell configuration procedure
    - Service-based Optimal Carrier Selection
    - CA Early Data Split during SCell activation
    - Procedure optimization of SCell Removal
    - Support for Uplink Intra-FR Inter-Band CA Between NR FDD Cells && Uplink Intra-Band CA
    - Trimmed Formal Parameters for CA
    - Extended the Range of Band+Bandwidth Combinations for CA
    - CA PDCCH Capacity Optimization

# Contents

## 2. Optional Features







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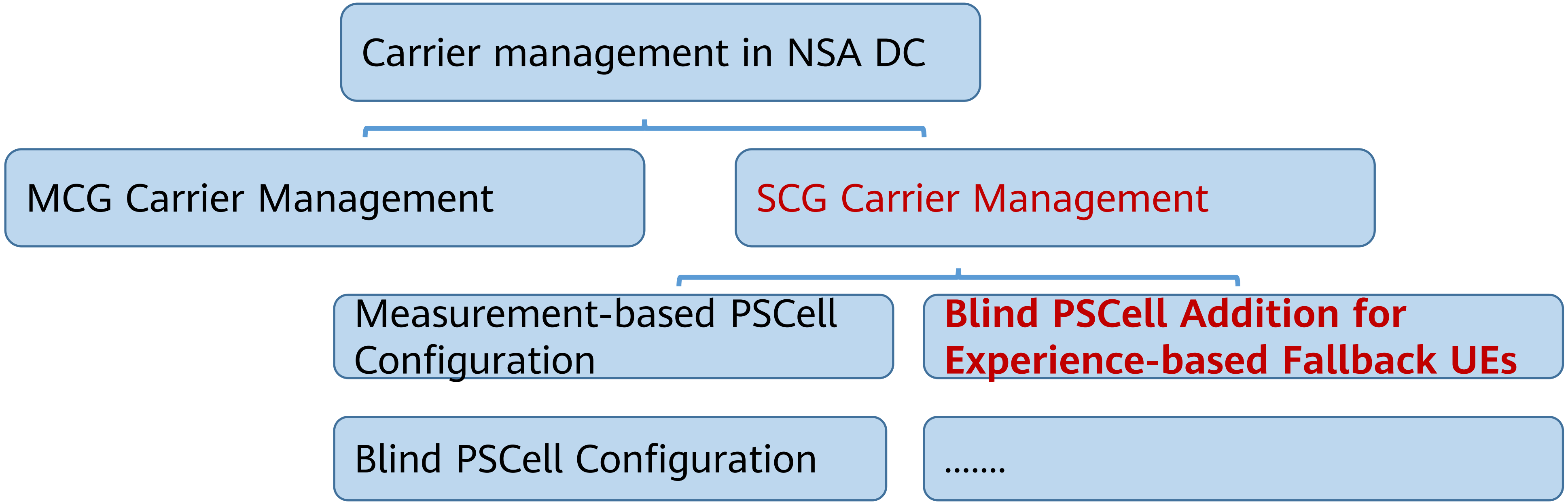
# The Enhancement of SCG Carrier Management

- Blind PSCell addition for experience-based fallback UEs for SCG carrier management is enhanced.



# Blind PSCell Addition for Experience-based Fallback UEs

- Different PSCell addition procedures can be triggered for UEs that fall back from SA networking to NSA networking due to poor user experience in different situations.

| Different types of cells are controlled by different parameter options | |
|---|---|
| LTE FDD cells | **LTE_FDD_NSA_SA_DL_SEL_OPT_SW** or **LTE_FDD_NSA_SA_UL_SEL_OPT_SW** option of the **EnodebAlgoExtSwitch.MultiNetworkingOptionOptSw** parameter |
| LTE TDD cells | **LTE_TDD_NSA_SA_DL_SEL_OPT_SW** option of the **EnodebAlgoExtSwitch.MultiNetworkingOptionOptSw** parameter |
| NR cells | **NSA_SA_DL_SEL_OPT_SW** or **NSA_SA_UL_SEL_OPT_SW** option of the **gNodeBParam.NetworkingOptionOptSw** parameter, and the **NSA_SA_DL_SEL_OPT_SW** or **NSA_SA_UL_SEL_OPT_SW** option of the **gNBOperator.OperatorInterRatPolicySw** parameter. |





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# Blind PSCell Addition for Experience-based Fallback UEs (Cont.)

Based on the preceding options

Selected

eNodeB initiates an SCG addition, and sends an SCG Addition message including NR CA carrier information to the NR side.

Check the **DIRECT_NR_HO_TO_EN_DC_SW** option

Selected

The PSCell is added during the SA-to-NSA handover to complete a direct switching from NR to EN-DC.

Deselected

The PSCell can be added for the NSA UE only after the SA-to-NSA handover.

Deselected

And the **NSA_BLIND_SCG_ADDITION_SWITCH** on the LTE side is selected

Blind PSCell Configuration is performed.

If failed, start the measurement PSCell Configuration.





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# Blind PSCell Addition for Experience-based Fallback UEs Deployment

- //Enabling uplink and/or downlink blind PSCell addition for experience-based fallback UEs
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_FDD_NSA_SA_DL_SEL_OPT_SW-1;
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_TDD_NSA_SA_DL_SEL_OPT_SW-1;
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_FDD_NSA_SA_UL_SEL_OPT_SW-1;
  - MOD ENODEBALGOEXTSWITCH: NrHandoverAlgoSwitch=DIRECT_NR_HO_TO_EN_DC_SW-1;
- //Disabling uplink or downlink blind PSCell addition for experience-based fallback UEs
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_FDD_NSA_SA_DL_SEL_OPT_SW-0;
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_TDD_NSA_SA_DL_SEL_OPT_SW-0;
  - MOD ENODEBALGOEXTSWITCH: MultiNetworkingOptionOptSw=LTE_FDD_NSA_SA_UL_SEL_OPT_SW-0;
  - MOD ENODEBALGOEXTSWITCH: NrHandoverAlgoSwitch=DIRECT_NR_HO_TO_EN_DC_SW-0;
- // The above commands are high-risk command.

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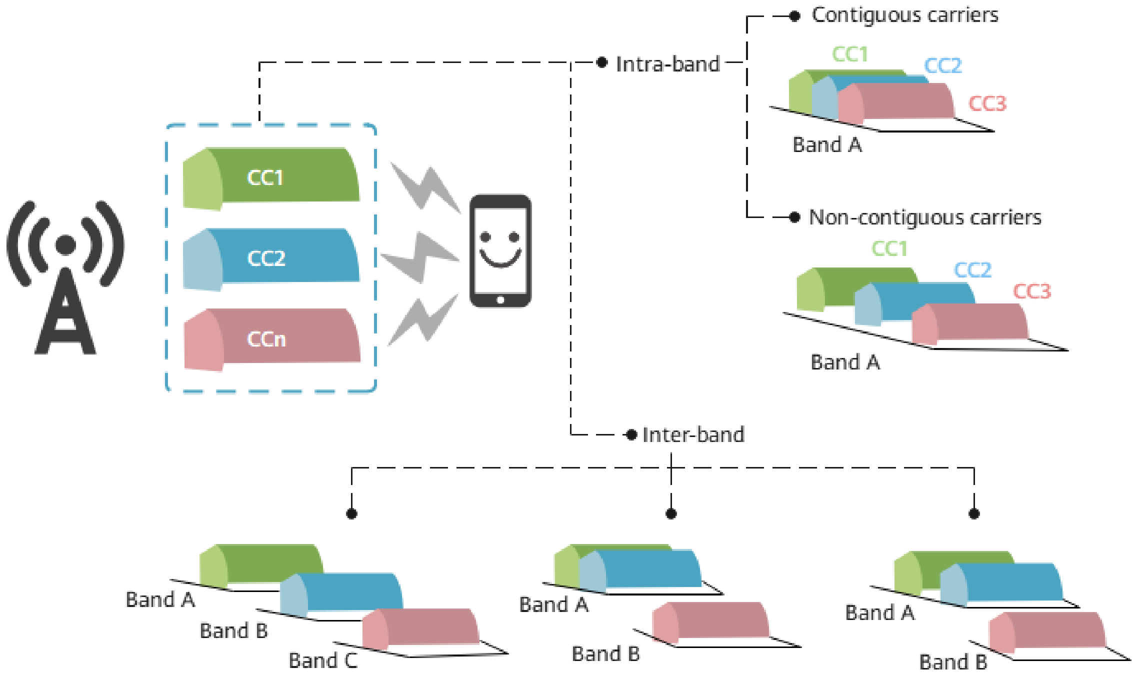
# 3CC CA Overview

- Three intra- or inter-band carriers can be aggregated to provide higher bandwidth and increase downlink peak user-perceived rates. 5G RAN6.1 introduces the following 3CC CA functions:
  - Downlink three-band 3CC aggregation
  - Downlink one-band 3CC aggregation



# 3CC CA Overview (Cont.)

- By default, 2CC aggregation is supported after downlink intra-FR inter-band CA is enabled by selecting the **INTRA_FR_INTER_BAND_CA_SW** option of the **NRDUCellAlgoSwitch**.CaAlgoSwitch parameter. To enable 3CC aggregation, the **NRDUCellCarrMgmt**.CaDlMaxCcNum parameter must be set to **DL3CC**.
- By default, 2CC aggregation is supported after downlink intra-band CA is enabled by selecting the **INTRA_BAND_CA_SW** option of the **NRDUCellAlgoSwitch**.CaAlgoSwitch parameter. To enable 3CC aggregation, the **NRDUCellCarrMgmt**.CaDlMaxCcNum parameter must be set to **DL3CC**.

# 3CC CA Network Analysis

- Benefits

Ranges of peak data rates achieved using downlink 3CC aggregation

| SCell Weight Type | Peak Data Rate Range |
|---|---|
| SRS-based | (A x 98% + B x 98%) to (A x 100% + B x 100%) |
| PMI-based | (A x 98% + B x 95%) to (A x 100% + B x 100%) |

# 3CC CA Network Analysis (Cont.)

- Impacts
  - System capacity

    A CA UE with SCells configured has only one RRC connection to the network. Such a UE consumes one sales unit of the license for the number of RRC_CONNECTED UEs. However, the CA UE consumes a hardware resource unit in each of its serving cells. With nCC aggregation for all UEs on the network, the maximum allowed number of RRC_CONNECTED UEs decreases to 1/n (n is an integer).

# 3CC CA Network Analysis (Cont.)

- Resource usage
  - Overall PRB usage of the network

    When CA is enabled, cell load can be rapidly balanced through carrier management and scheduling to help utilize idle resources and increase the overall PRB usage of the network.
  - PUCCH and PUSCH overheads

    Each CA UE sends the ACK/NACK and CSI related to its SCells in its PCell with the PUCCH. When the PUSCH is not scheduled, the UE sends the information over the PUCCH. When the PUSCH is scheduled, the UE sends the information over the PUSCH. Therefore, the PUCCH overhead or the signaling overhead on the PUSCH increases.

# 3CC CA Network Analysis (Cont.)

- Impacts
  - Overall throughput in the entire network

    CA does not directly affect network capacity. However, when the resources on a network have not been exhausted, CA increases the overall resource usage and network throughput.

# 3CC CA Feature Deployment

- Dependency

| | |
|---|---|
| **Hardware Requirements** | • Base Station Models<br>3900 and 5900 series base stations. 3900 series base stations must be configured with the BBU3910.<br>DBS3900 LampSite and DBS5900 LampSite. DBS3900 LampSite must be configured with the BBU3910.<br>• Boards<br>Main control boards: All NR-capable main control boards support this feature. For details, see the related BBU technical specifications in 3900 & 5900 Series Base Station Product Documentation.<br>Baseband processing units: Cells on NR-capable baseband processing units other than the UBBPfw can act as PCells for UEs. Cells on all NR-capable baseband processing units can act as SCells.<br>• RF Modules<br>All NR-capable RF modules that work in low frequency bands support this feature. |
| **Software Requirements** | • Prerequisite Functions<br>Intra-FR inter-band CA<br>Intra-band CA<br>• Mutually Exclusive Functions<br>SRS interference avoidance<br>SRS remote interference avoidance<br>SRS interference coordination based on self-contained and uplink slots |

# 3CC CA Feature Deployment (Cont.)

- Dependency

| | |
|---|---|
| **Networking Requirements** | • Coverage<br>The coverage areas provided by the cells involved in CA must overlap. The smaller the overlapping range, the smaller the area where CA takes effect.<br>• Cells<br>The **NRCellRelation** MO has been configured.<br>Network planning must mitigate PCI conflicts between intra-frequency cells. |
| **NE Requirements** | This feature is implemented on the gNodeB. |

# 3CC CA Feature Deployment (Cont.)

- Licenses
  - Feature licenses
    - None

# 3CC CA Feature Deployment (Cont.)

- Activation
  - //Setting the maximum number of downlink carriers to enable downlink 3CC aggregation
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaDlMaxCcNum=DL3CC;
  - //(Optional) Configuring an operator-defined CA band+bandwidth combination
    - ADD GNBCUSTCABANDCOMB: CustCaBandCombId=1, BandwidthCombSet=1, FrequencyBand1=N77, FrequencyBandwidth1=CELL_BW_100M, FrequencyBand2=N77, FrequencyBandwidth2=CELL_BW_90M, FrequencyBand3=N41, FrequencyBandwidth3=CELL_BW_100M;
- Deactivation
  - //Disabling downlink 3CC aggregation
    - MOD NRDUCELLCARRMGMT: NrDuCellId=0, CaDlMaxCcNum=NOT_CONFIG;

# 3CC CA Feature Verification

- Activation verification
  - Provided that CA UEs are available on the network, 3CC CA has taken effect if any counter related to downlink 3CC CA returns a non-zero value.

    The following are the counters related to downlink 3CC CA.

| Counter ID | Counter Name |
|---|---|
| 1911833653 | N.3CC.CA.ThpVol.DL |
| 1911833651 | N.3CC.CA.ThpVol.DL.LastSlot |
| 1911833654 | N.3CC.CA.ThpTime.DL.RmvLastSlot |

# 3CC CA Feature Verification (Cont.)

- Network monitoring
  - Observe the average downlink UE throughput to check whether the UE data rate increases after this feature is enabled.

    Average downlink UE throughput: User Downlink Average Throughput (DU)
  - Observe the RLC traffic volume to UEs in the 3CC aggregation state in a cell, that is, the total volume of downlink data sent at the RLC layer in a cell to SCell-activated CA UEs in the 3CC aggregation state.

    RLC traffic volume to UEs in the 3CC aggregation state in a cell = N.3CC.CA.ThpVol.DL
  - Observe the average throughput of SCell-activated UEs in the 3CC aggregation state, which is calculated using the following formula: (N.3CC.CA.ThpVol.DL – N.3CC.CA.ThpVol.DL.LastSlot)/N.3CC.CA.ThpTime.DL.RmvLastSlot.



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# Q&A

1. Which of the following 3CC CA functions are introduced to 5G RAN6.1?

   A. Downlink two-band 3CC aggregation

   B. Downlink three-band 3CC aggregation

   C. Downlink one-band 3CC aggregation

# Q&A

2. Which of the following statements about 3CC CA is correct?
   - A. 3CC CA works in both the uplink and downlink.
   - B. 3CC CA works only in the downlink.
   - C. 3CC CA does not require intra- or inter-band CA to be enabled.

# Section Summary

- In this version, the following enhancements are added to 3CC CA:
  - Downlink three-band 3CC aggregation
  - Downlink one-band 3CC aggregation

# Thank You

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