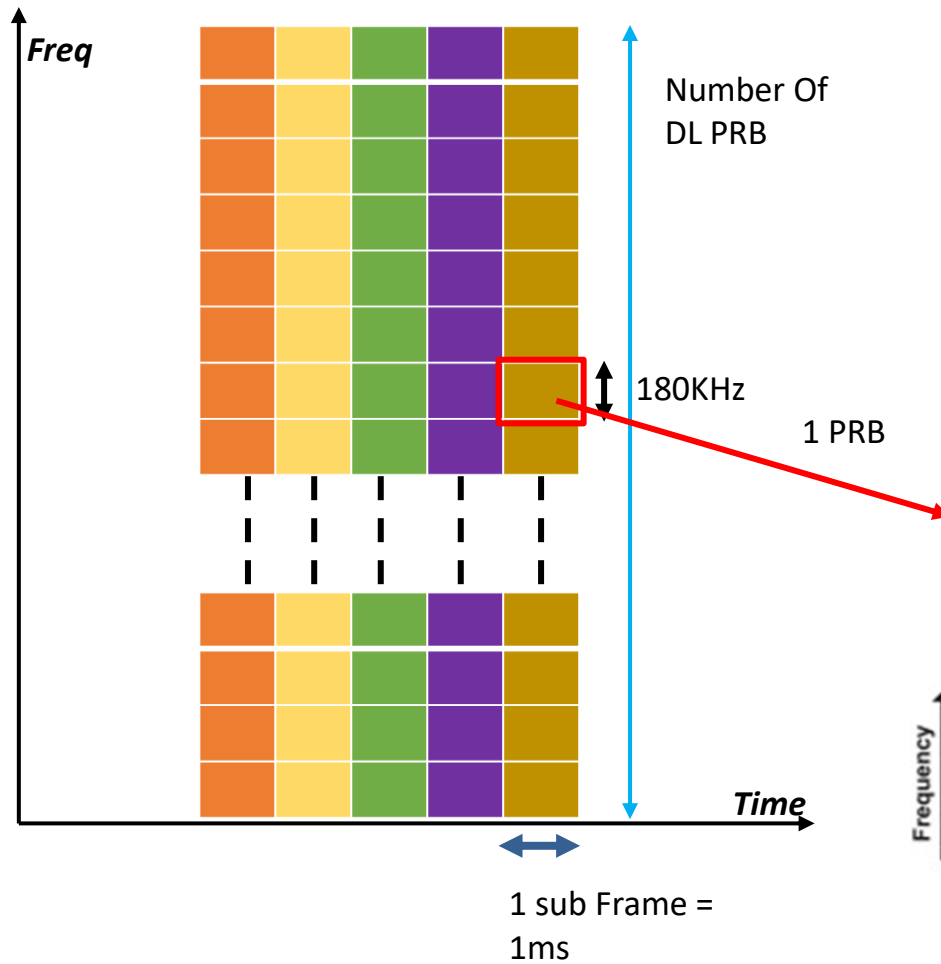
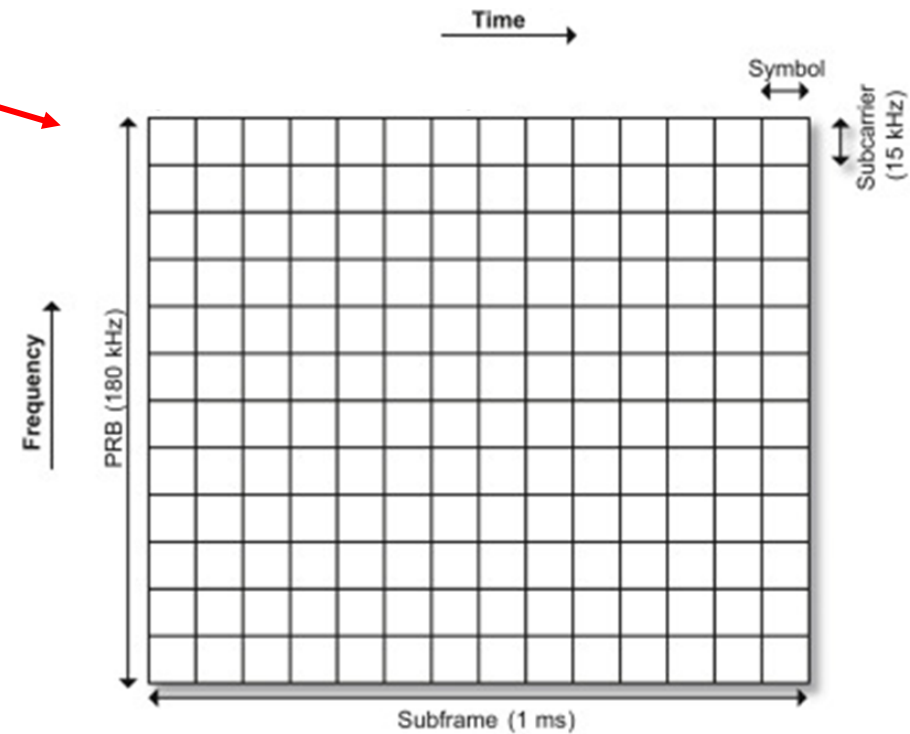


PDCCH

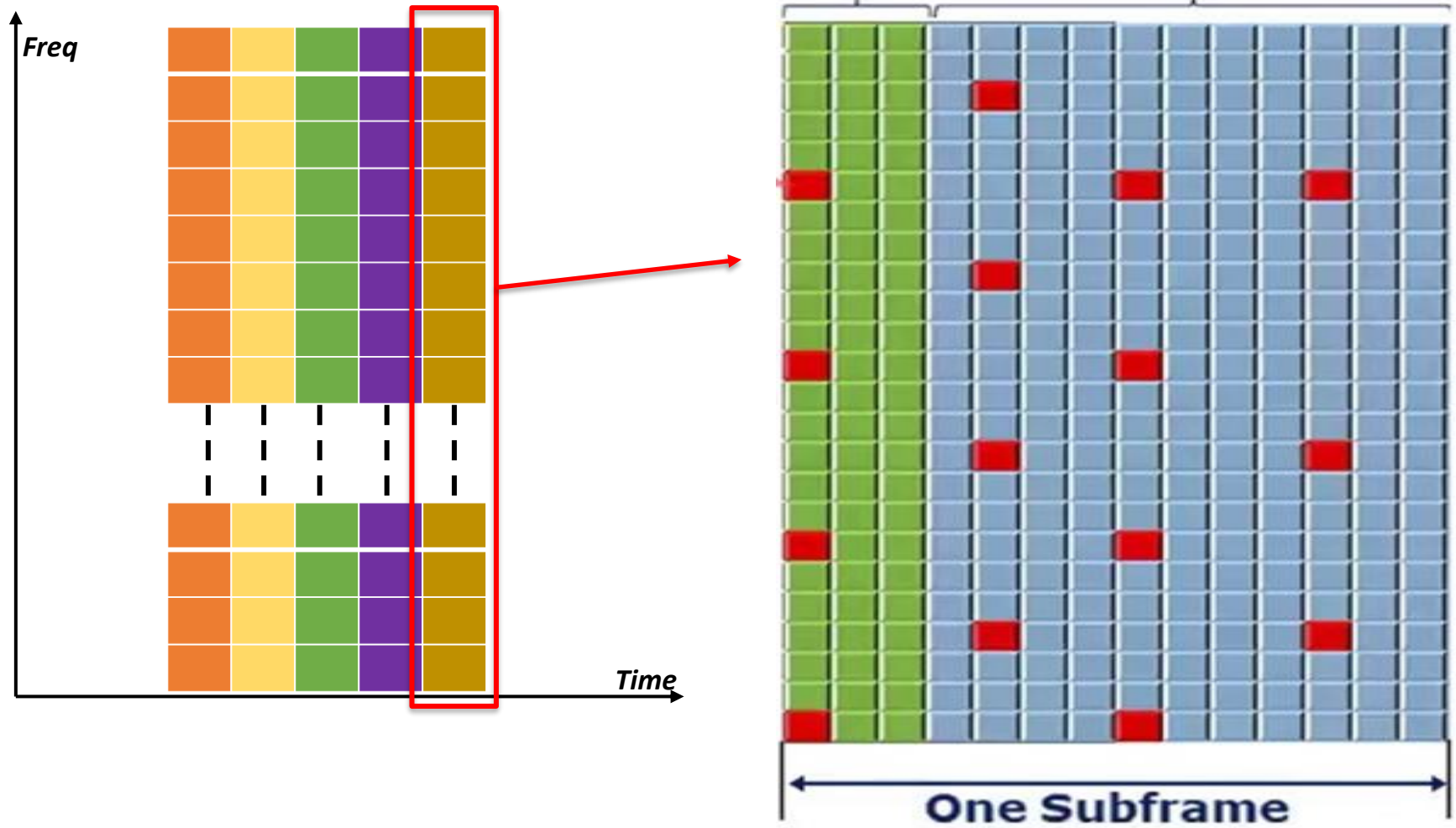
Time frequency resources in LTE.



| BW [MHz] | 1.4 | 3 | 5 | 10 | 15 | 20 |
|----------|-----|----|----|----|----|-----|
| # PRB | 6 | 15 | 25 | 50 | 75 | 100 |



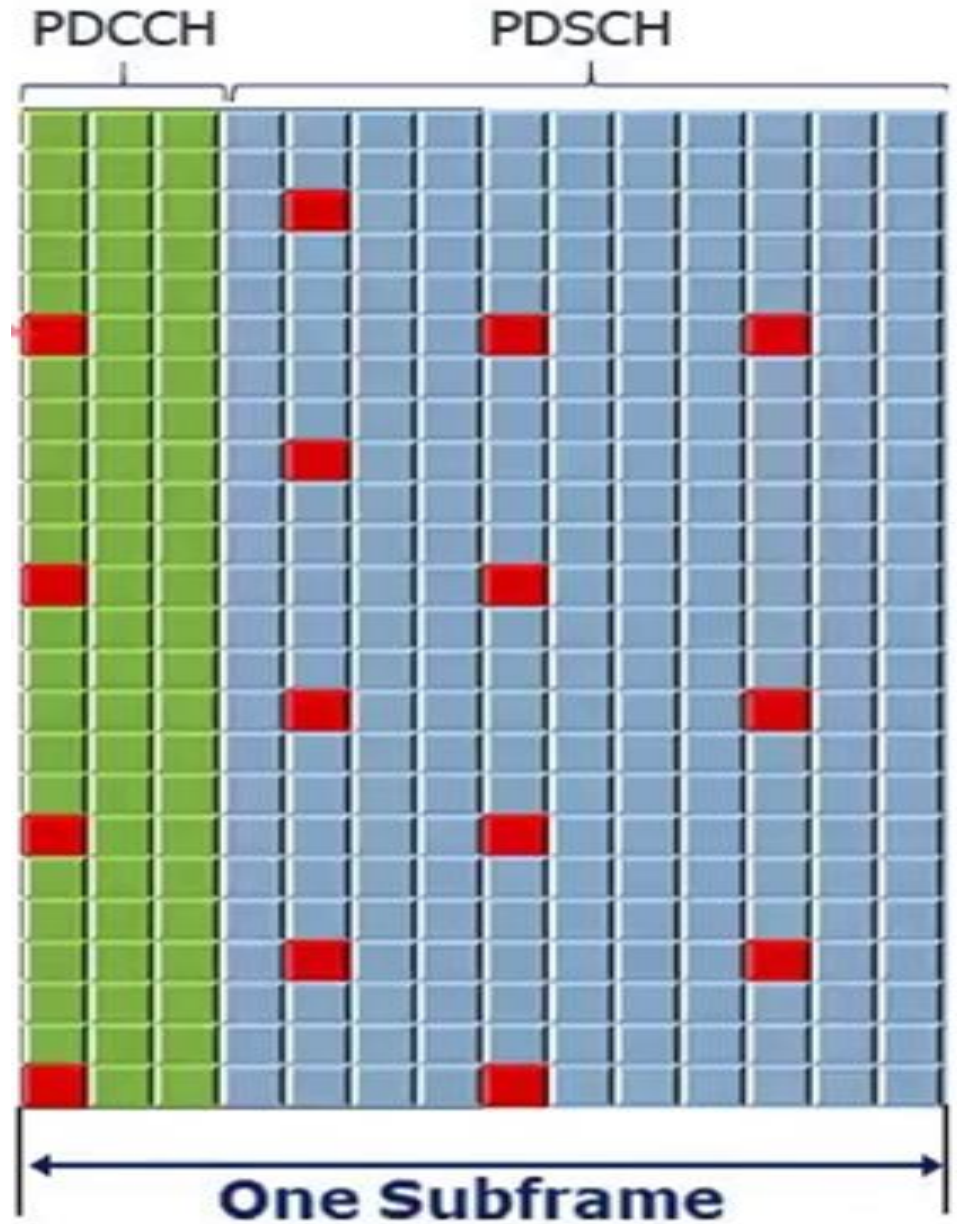
Time frequency resources in LTE.



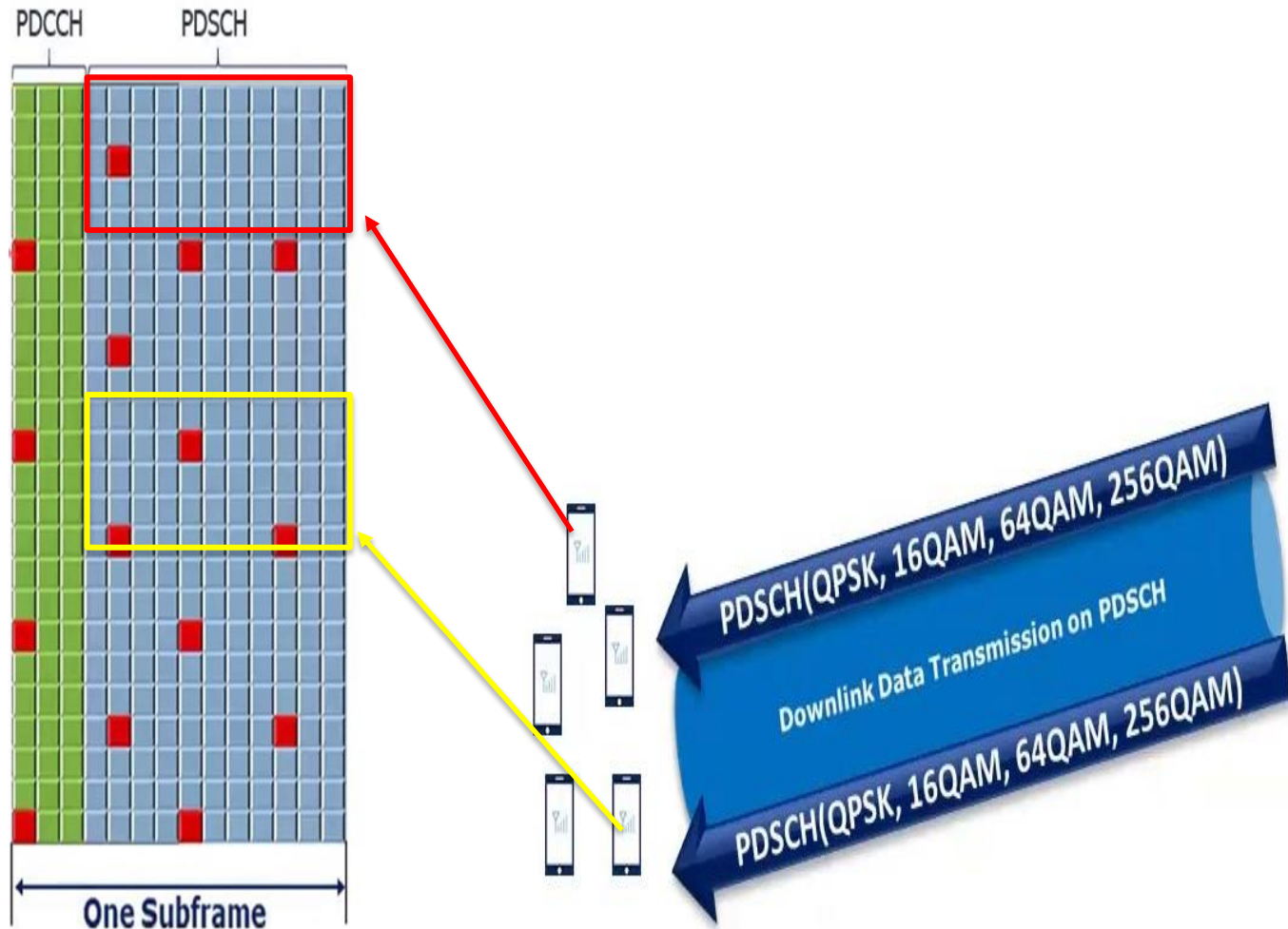
PDCCH Vs PDSCH Channel

Green Area is called control area and it conveys PDCCH , PCFICH ,PHICH

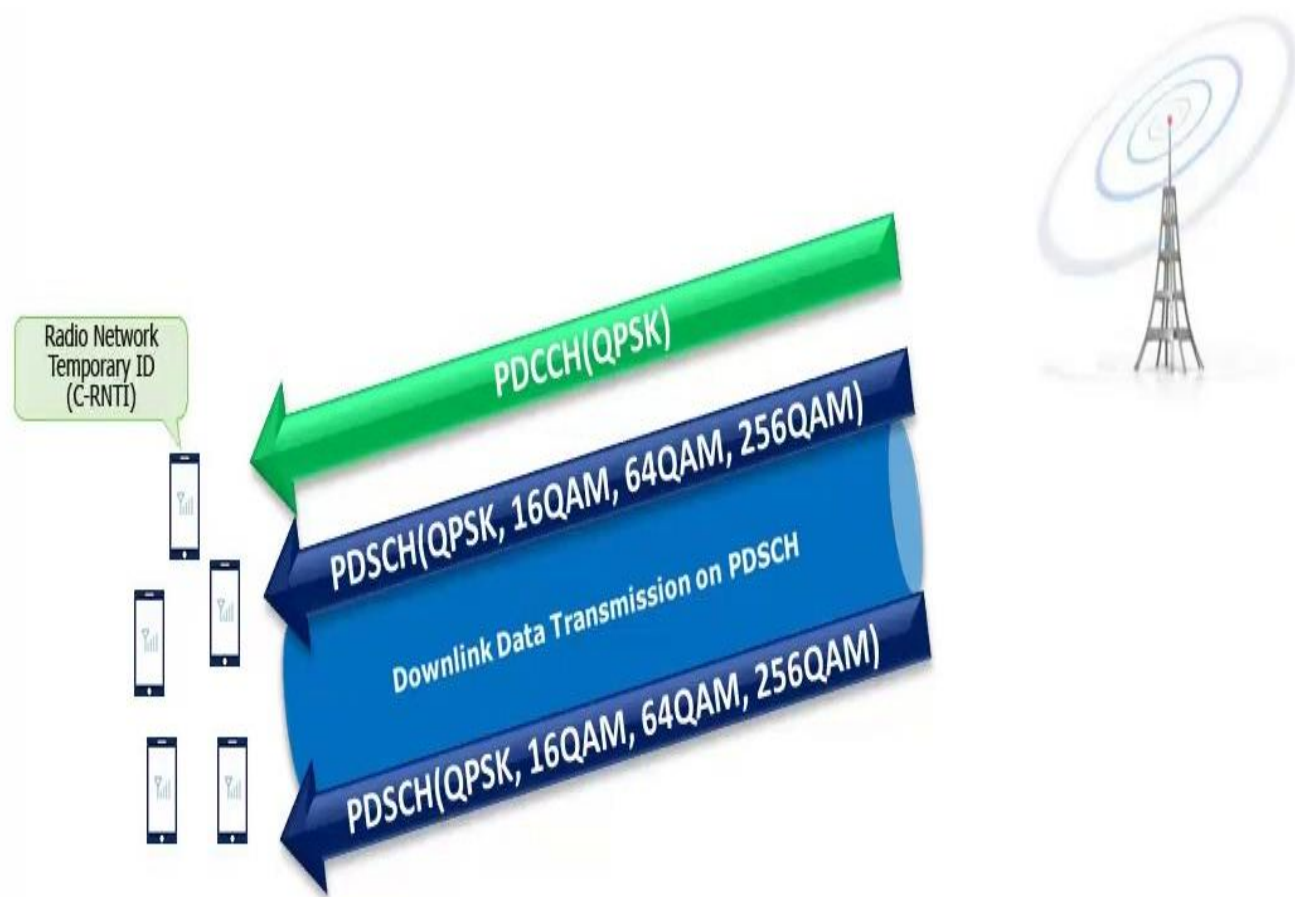
Because the majority part of this area is allocated to PDCCH channel , sometimes it may be called PDCCH area

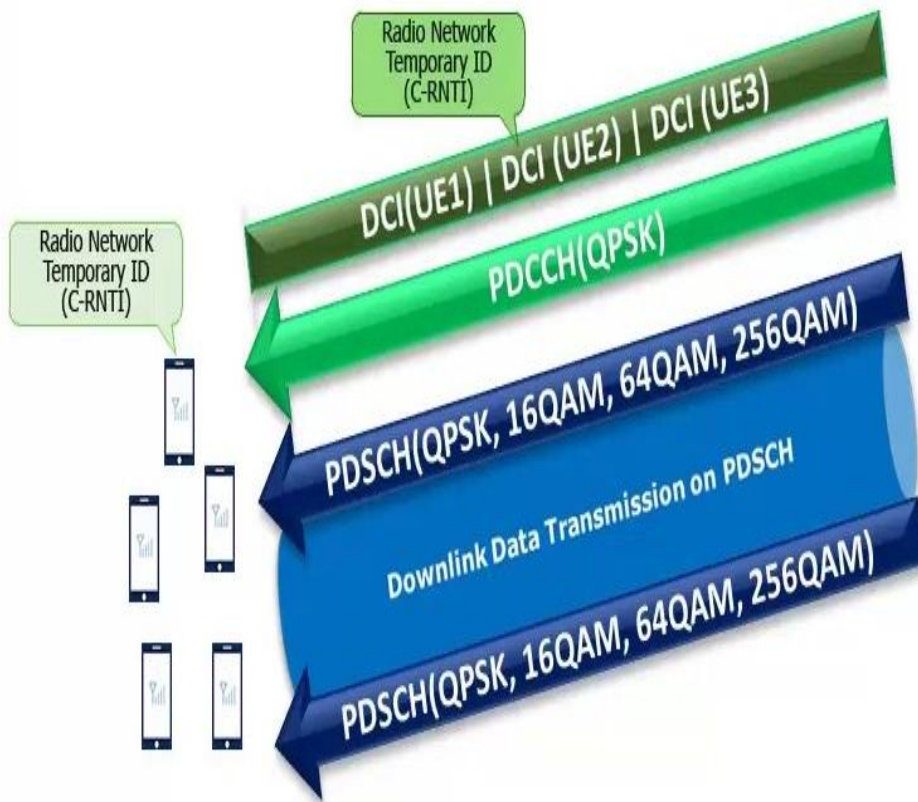


PDSCH is a shared channel and PRBs are distributed among all scheduled UEs. How does a specific UE know which part of PRBs carries it's own data?

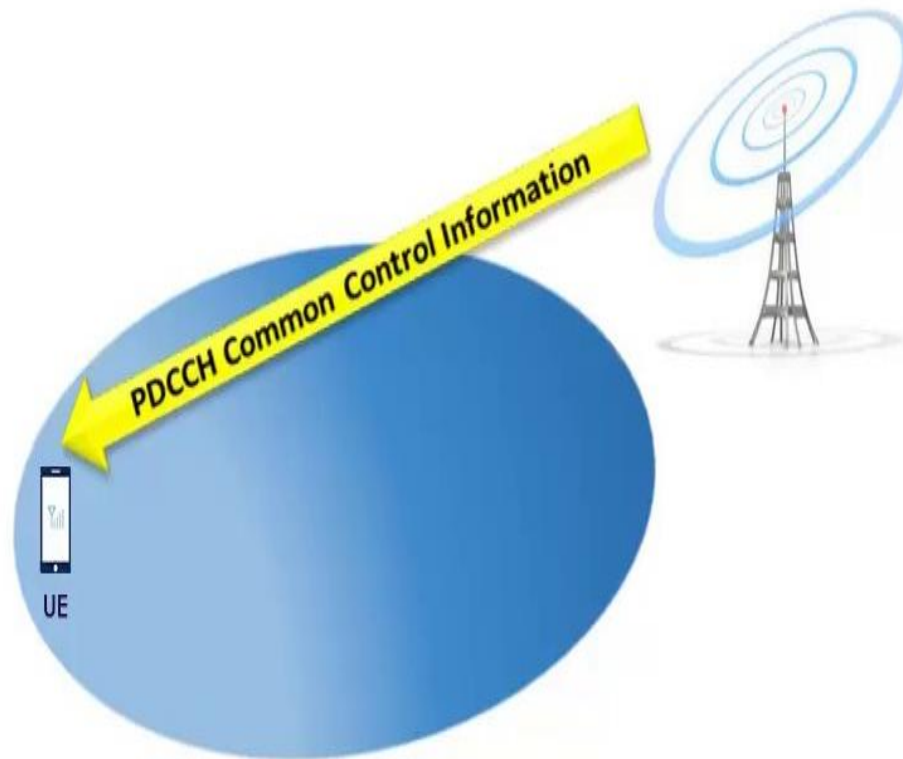


PDCCH is designed to convey all required information that UEs need to find and decode their data

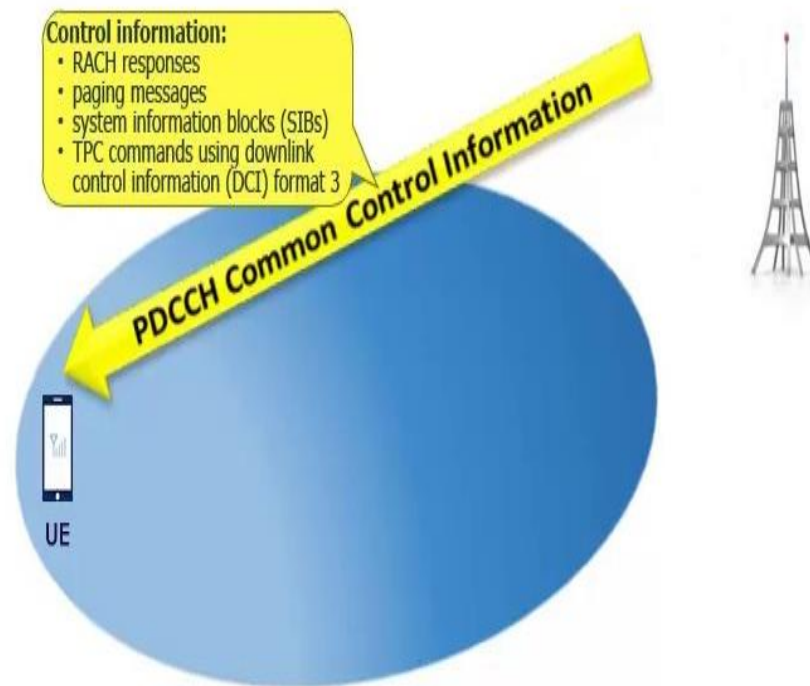




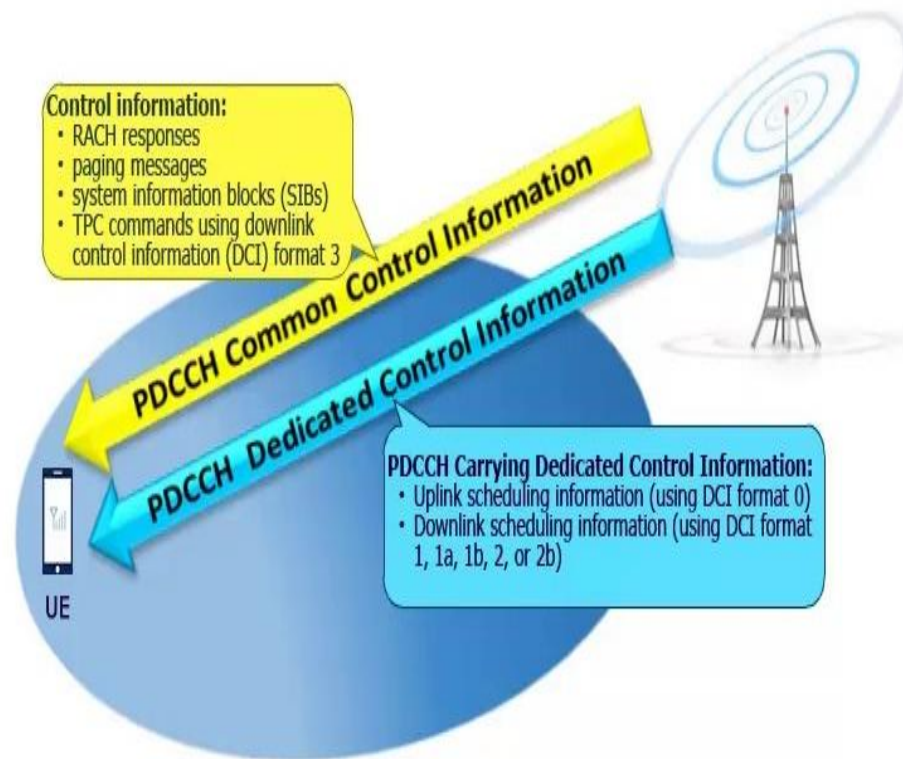
LTE Downlink Traffic: **Physical Downlink Shared Channel(PDCCH)**



LTE Downlink Traffic: **Physical Downlink Shared Channel(PDCCH)**

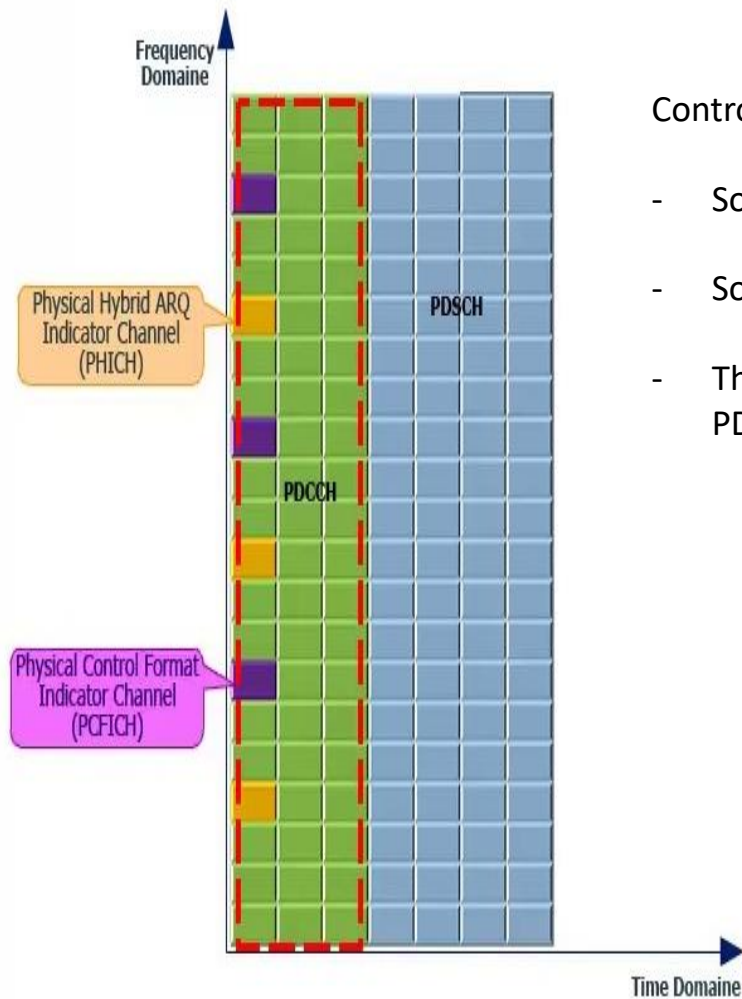


LTE Downlink Traffic: **Physical Downlink Shared Channel(PDCCH)**



PDCCH
Resource Allocation
CCE Adjustment

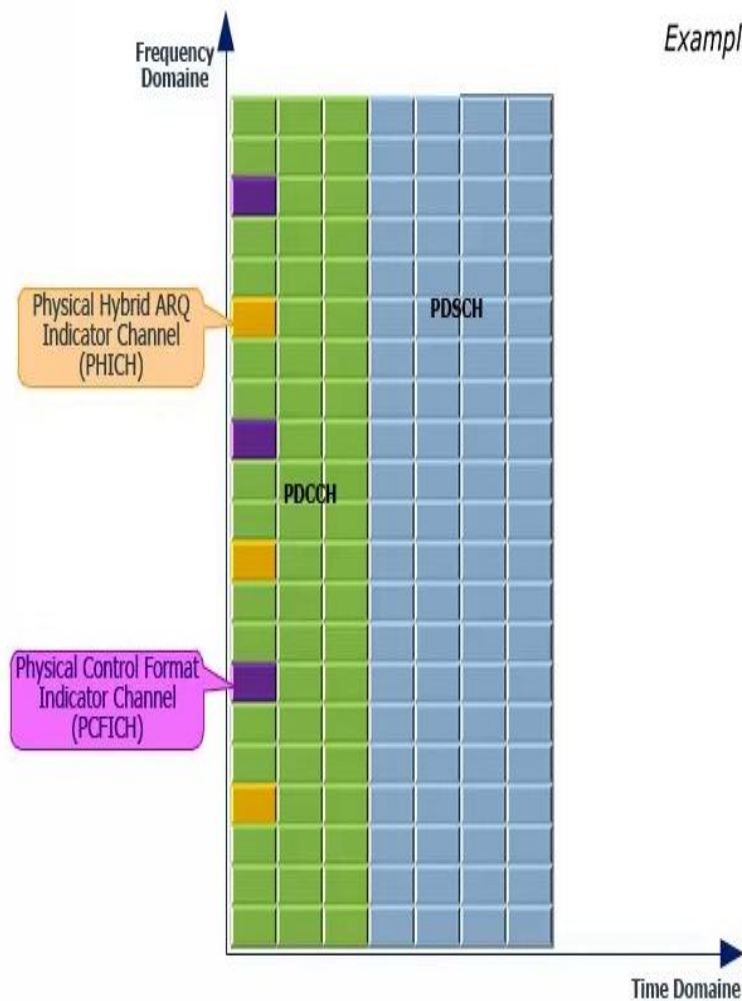
LTE Downlink Traffic: Physical Downlink Shared Channel(PDSCH) - PDCCH & CCE



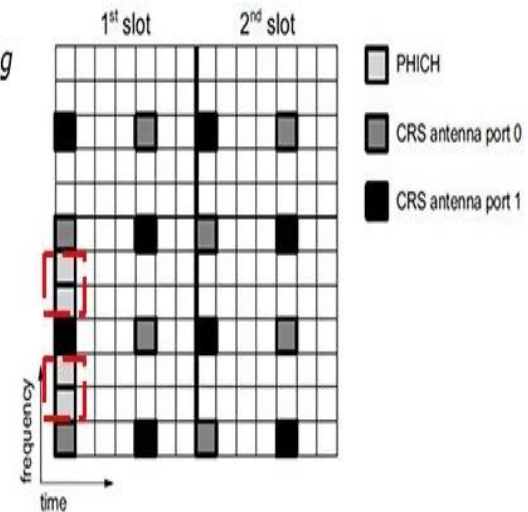
Control Region carries PCFICH , PHICH , PDCCH

- Some REs are reserved for RS
- Some REs are allocated to PCFICH & PHICH
- The remaining part is divided to CCEs and allocated to PDCCH of UEs

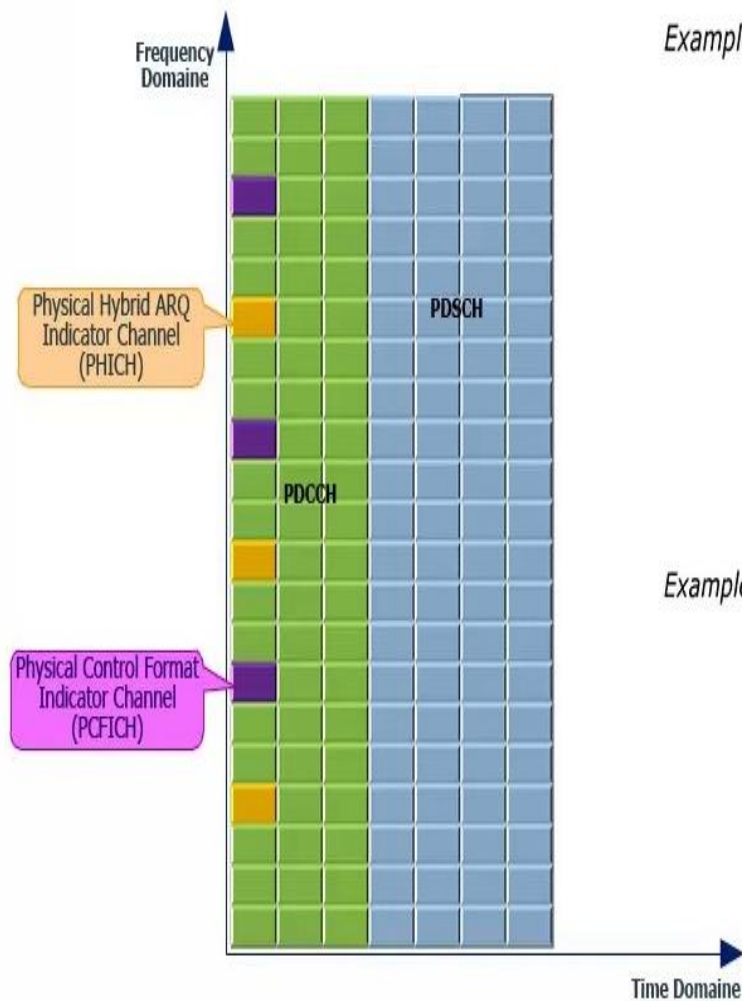
LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - PDCCH & CCE



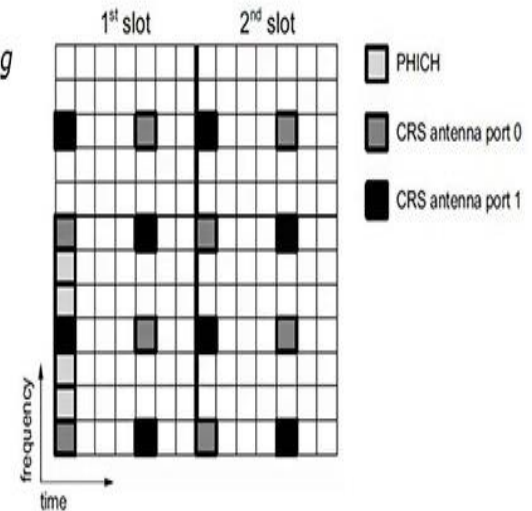
Example of PHICH Mapping



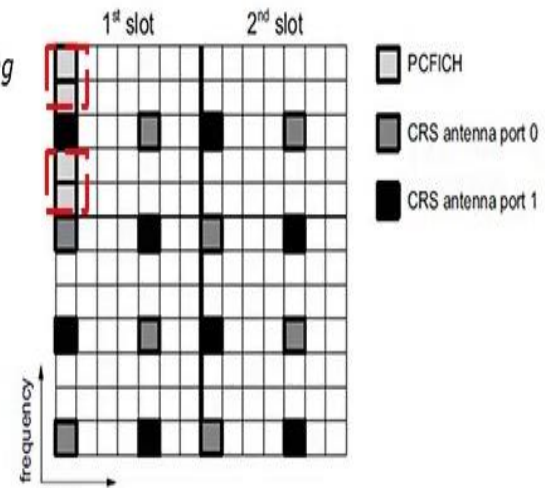
LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - PDCCH & CCE



Example of PHICH Mapping

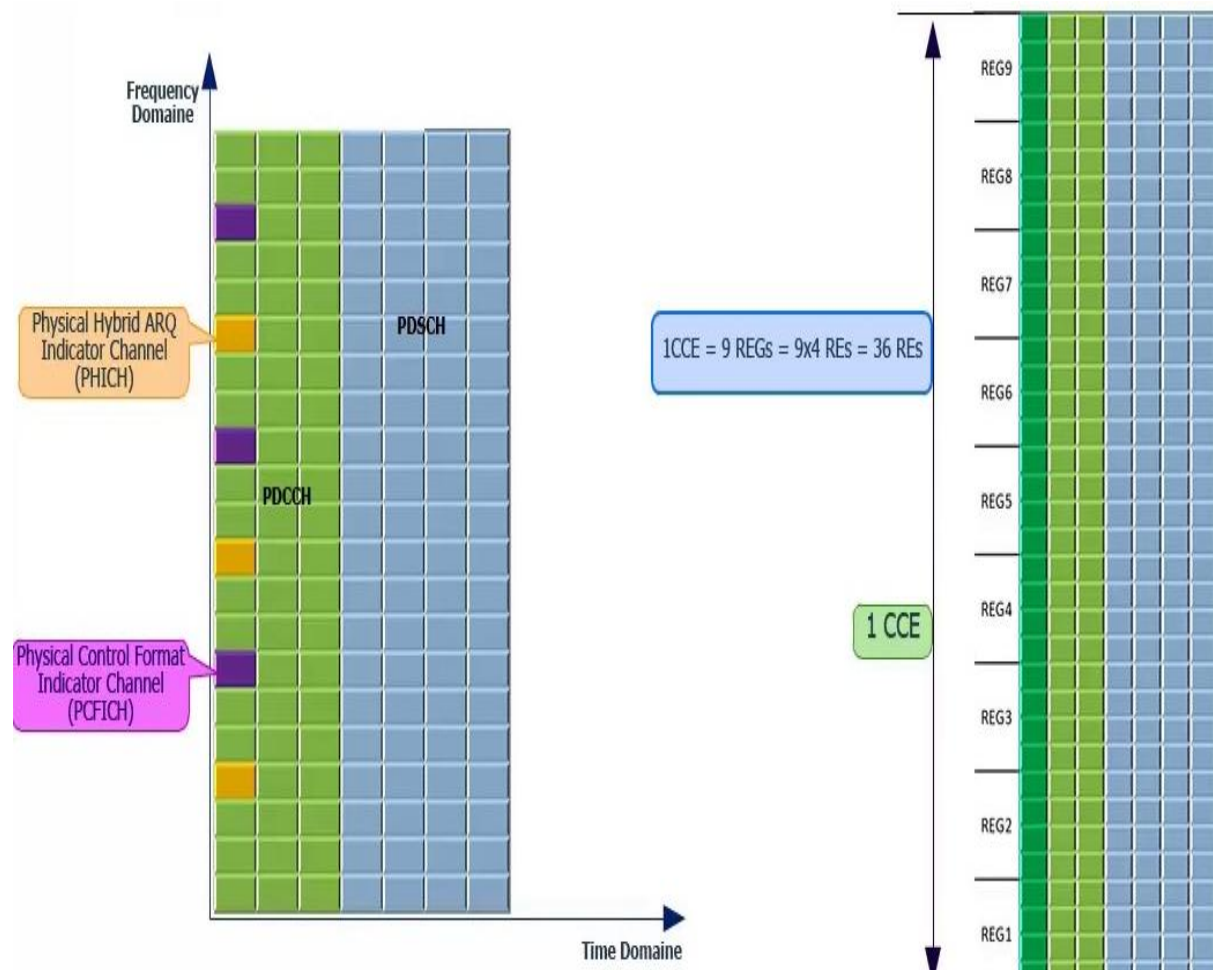


Example of PCFICH Mapping



What is CCE.

- Resource Allocation in PDCCH is based on CCE
- Each CCE is equal to 9 REG
- Each REG contains 4 RE.
- 1 or 2 or 4 or 8 CCE can be allocated to one PDCCH channel
- 1 CCE = Aggregation Level 1
- 2CCE = Agg LVL 2
- 4 CEE = Agg LVL 4
- 8 CCE = Agg LVL 8

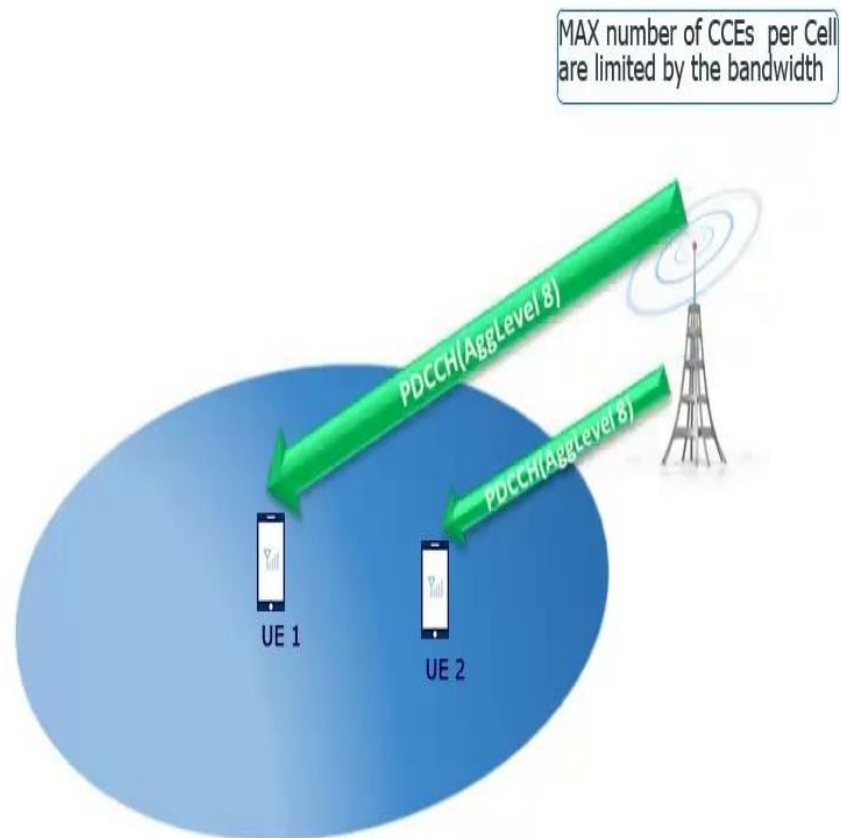


Why CCE & AGG Level is important

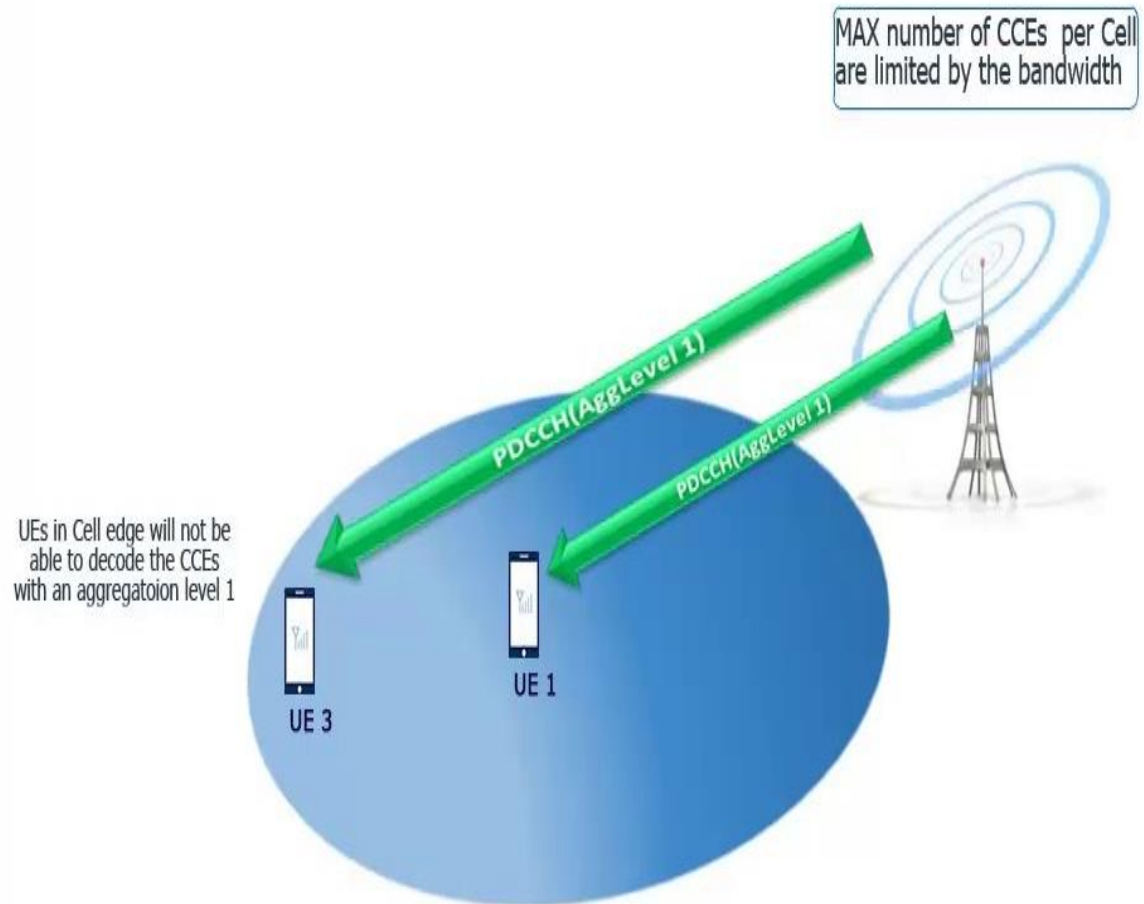
- Total resources in control region is limited
- So we have restriction on number of CCE per TTI → it will limit number of user that LTE system can Schedule per TTI
- The more users are scheduled per TTI , The greater DL user throughput will be experienced.
- PDCCH resources impose a critical restriction on LTE system and PDCCH resource management plays a crucial role in LTE system.

Which Agg Level must be selected..

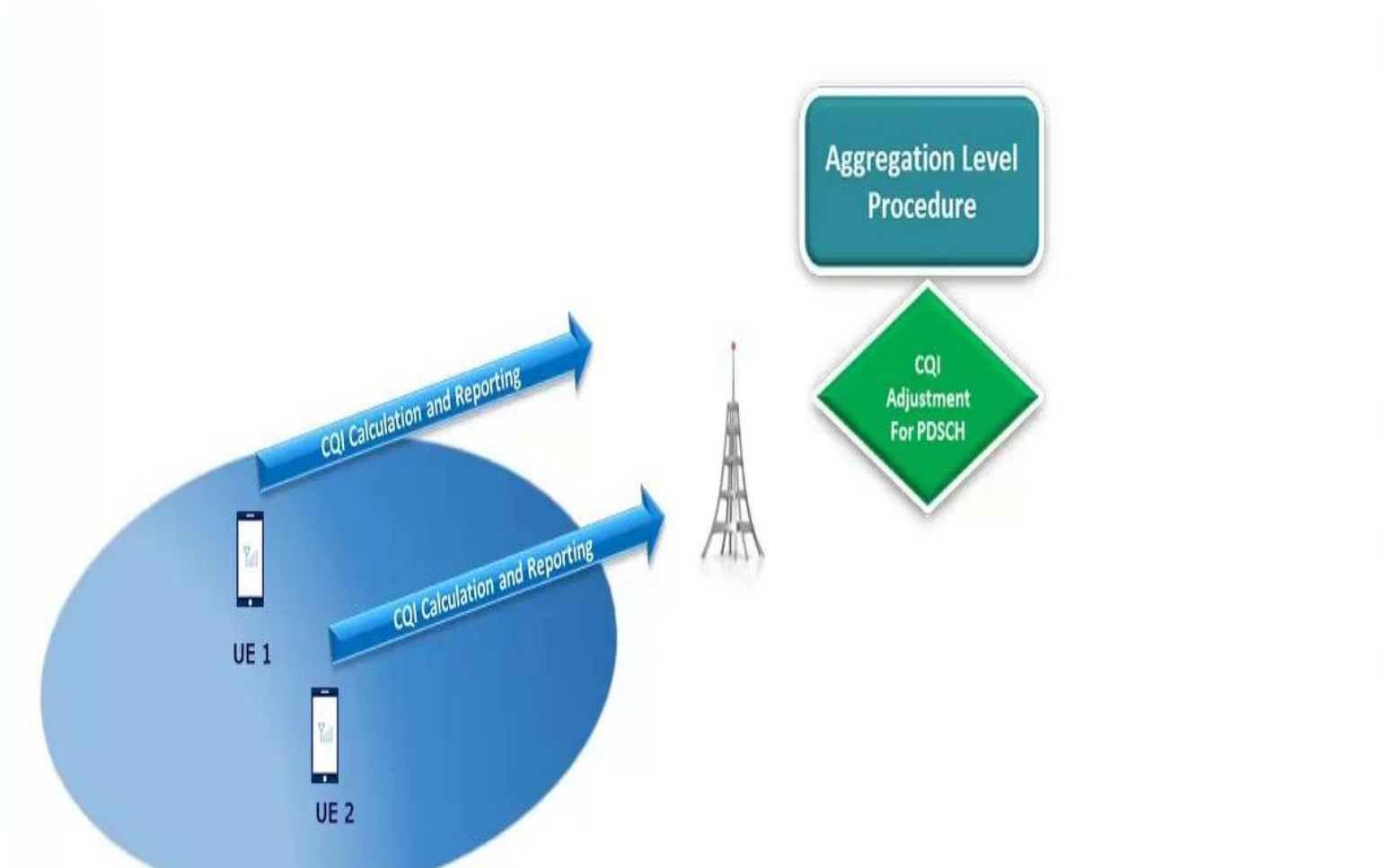
- If we use Agg level 8 for all UEs , we are wasting PDCCH resource because cell center UEs don't need AGG LVL8



- If we used Agg level 1 for all UEs , detecting the PDCCH will be impacted for cell edge UEs , and if UE cannot detect PDCCH , cannot receive it's data.
- Therefore, LTE system need an approach to adjust CCE for each UE based on it's RF condition.



- eNB uses CQI to adjust CCE Agg Level for each UE.



LTE Downlink Traffic: PDCCH Settings - PDCCH Aggregation Level Adaptation

PDCCH aggregation level adaptation Procedure

CQI = Reported CQI &
CQI Adjustment Algo

$SINR(RS)$ = Based on CQI

LTE Downlink Traffic: PDCCH Settings - PDCCH Aggregation Level Adaptation

PDCCH aggregation level adaptation Procedure

CQI = Reported CQI &
CQI Adjustment Algo

$SINR(RS)$ = Based on CQI

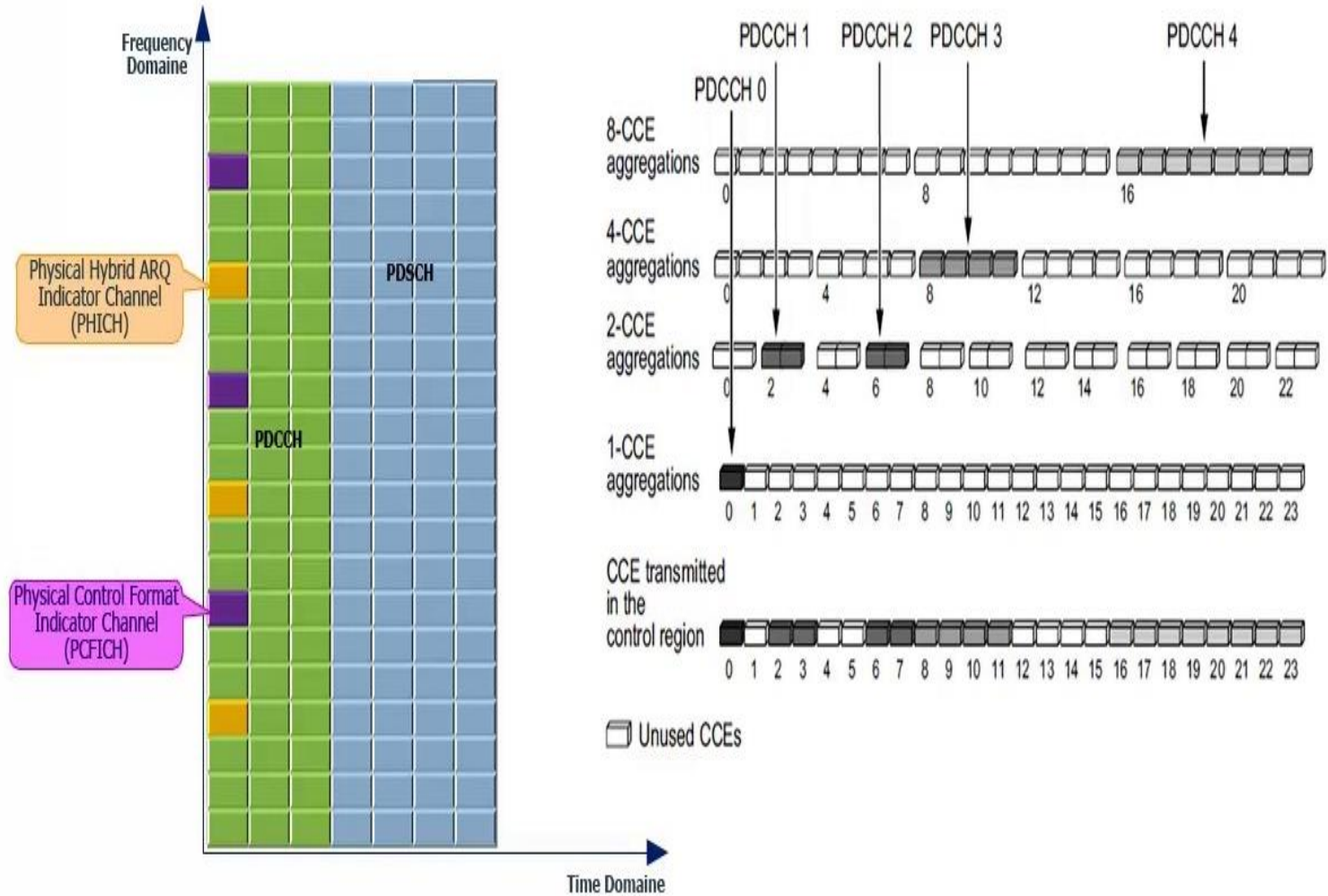
$SINR(PDCCH)$ = Based on $SINR(RS)$

LTE Downlink Traffic: PDCCH Settings - PDCCH Aggregation Level Adaptation

PDCCH aggregation level adaptation Procedure



LTE Downlink Traffic: **Physical Downlink Shared Channel(PDCCH)** - PDCCH & CCE



DCI

LTE Downlink Traffic: **Physical Downlink Shared Channel(PDCCH)** - Downlink Control Information (DCI)

Format 0: Used for uplink PUSCH allocations.

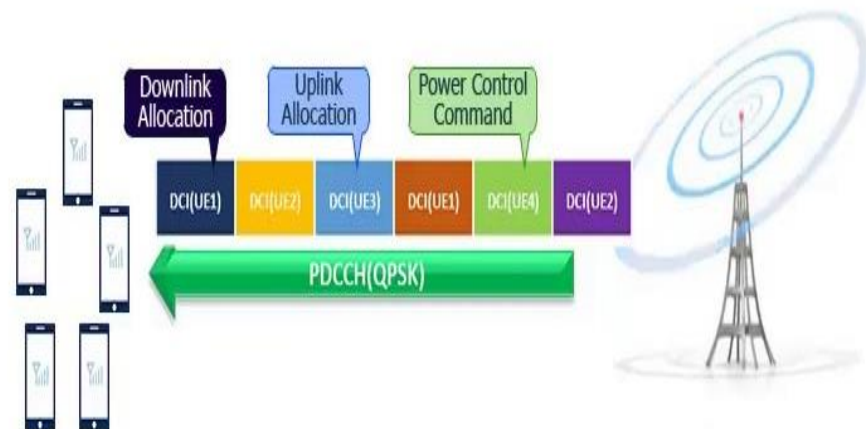
Format 1: Used for type 0 or type 1 downlink PDSCH allocations. (Primary)

Format 1A,1B,1C and 1D: Used for downlink PDSCH allocations.(used only for virtual resource blocks and antenna precoding)

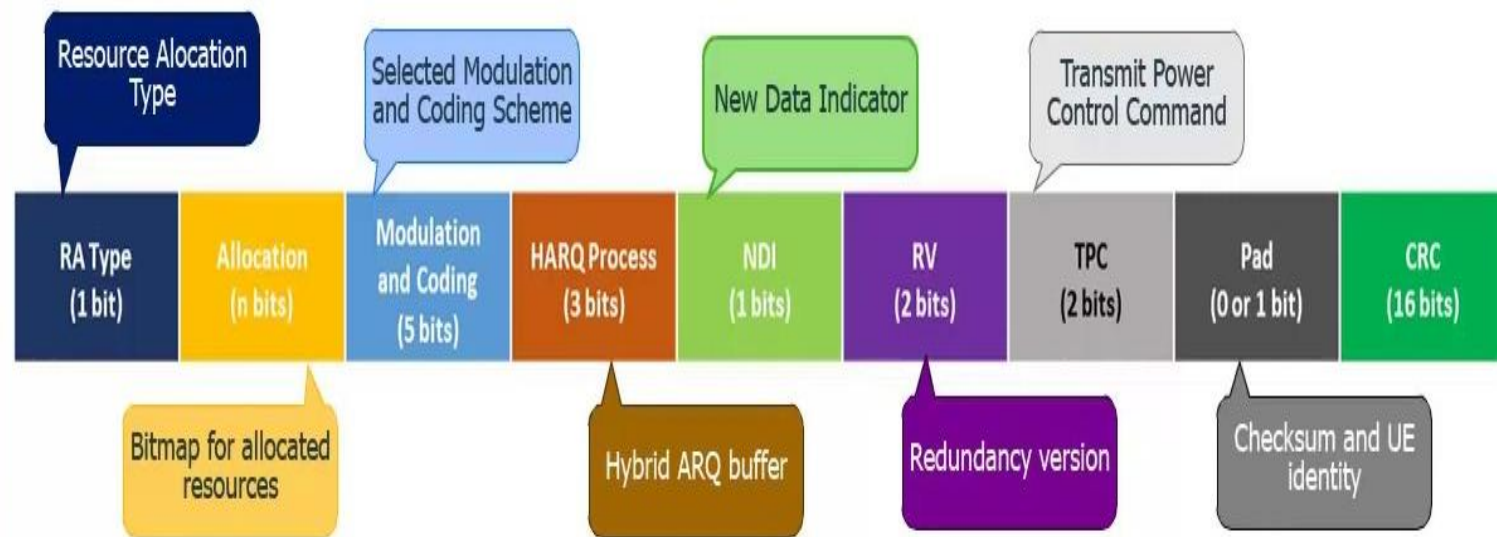
Format 2 and 2A: Used for type 0 or type 1 downlink PDSCH allocations in spatial multiplexing(multiple antenna) systems.

Format 3 and 3A: Used for PUCCH and PUSCH power adjustments.

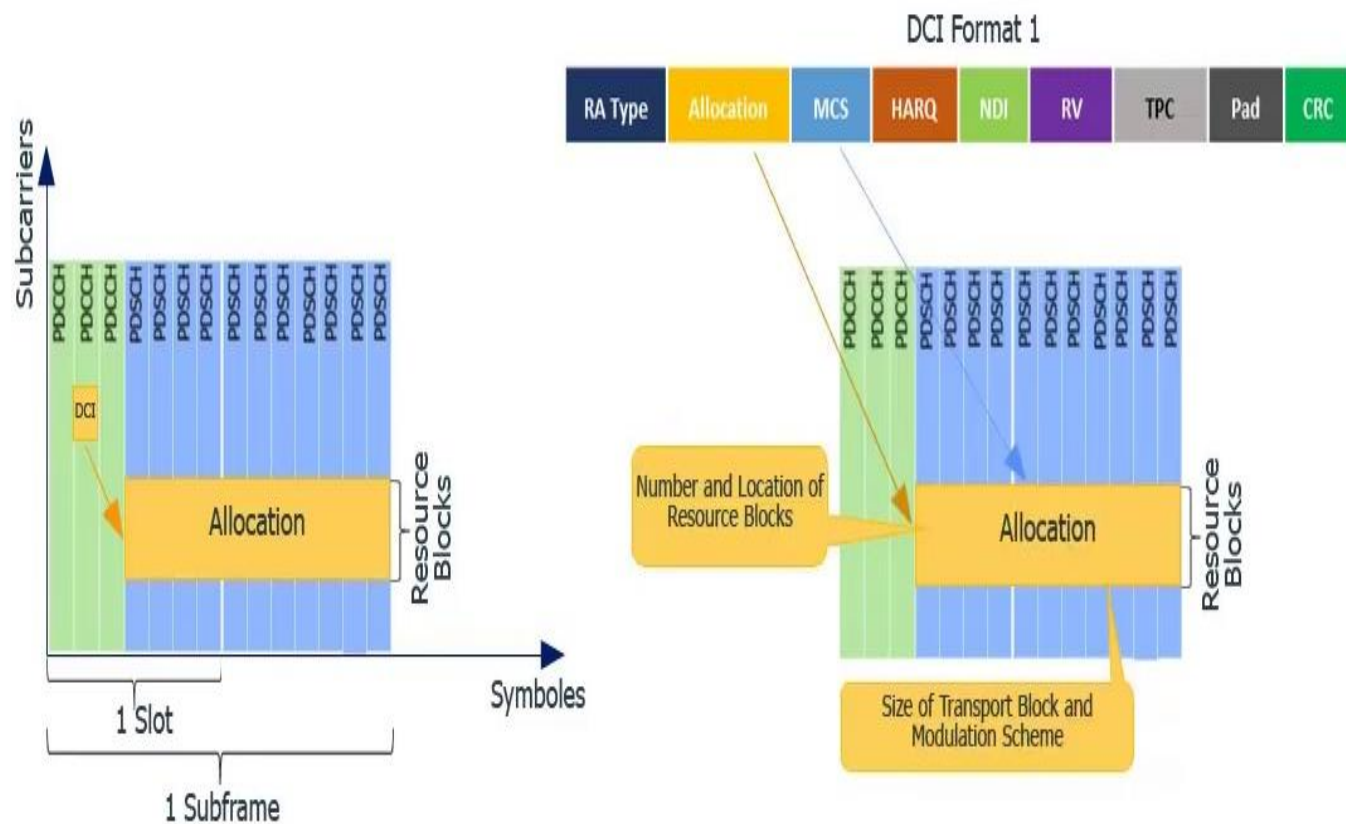
Format 4: Used for the scheduling of PUSCH with multi-antenna port transmission mode.



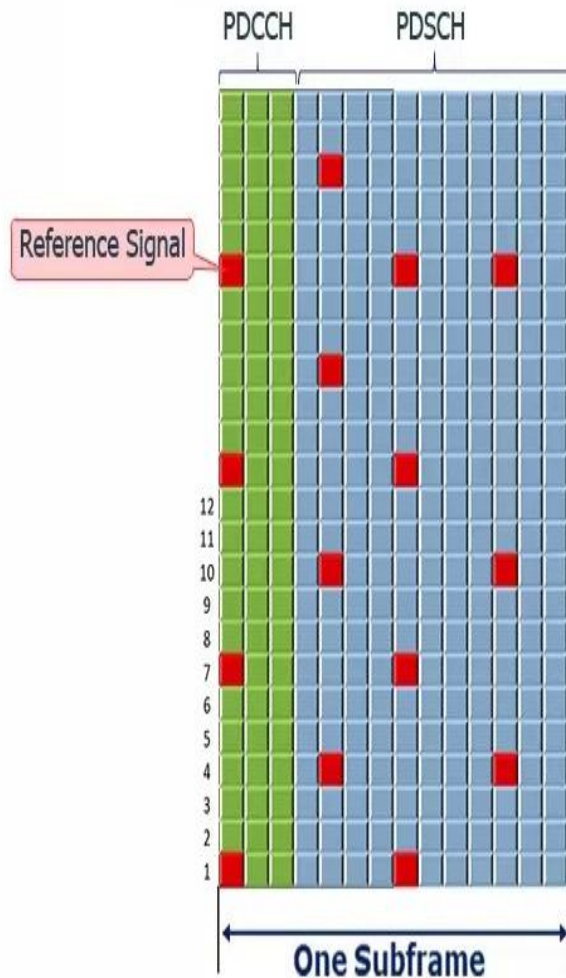
LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - DCI Format 1



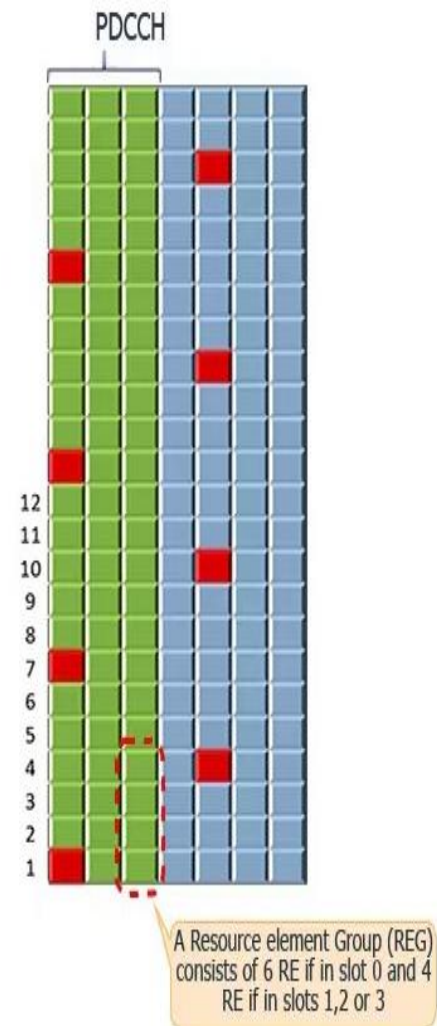
LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - Downlink Allocation



LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH)

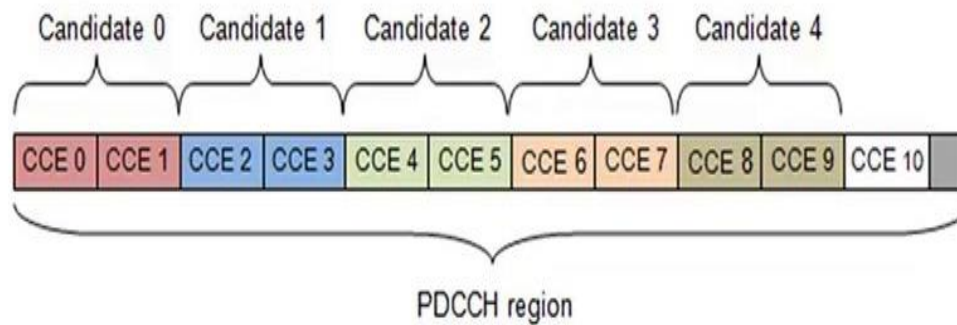


Each UE will scan one or more PDCCHs looking at the CCEs to determine whether they contain information that pertains to that UE



LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - PDCCH & CCE

Aggregation Level $L = 2$

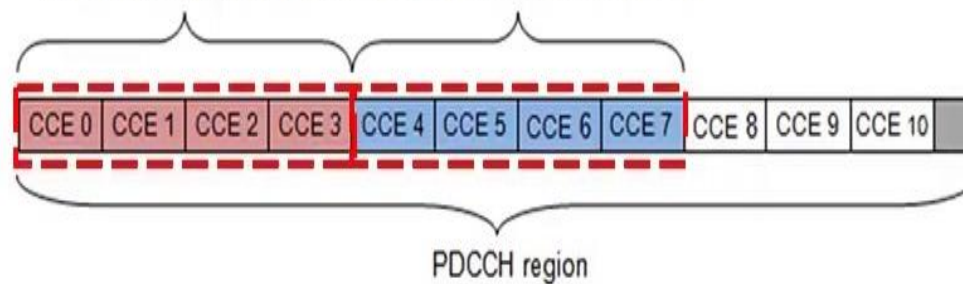


CCE Unused CCE REs not assigned to CCE as not enough REs to create a CCE

LTE Downlink Traffic: Physical Downlink Shared Channel(PDCCH) - PDCCH & CCE

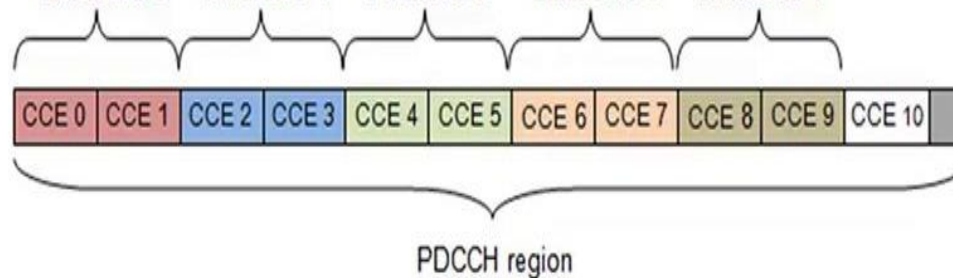
Aggregation Level $L = 4$

PDCCH allocation candidate 0 PDCCH allocation candidate 1



Aggregation Level $L = 2$

Candidate 0 Candidate 1 Candidate 2 Candidate 3 Candidate 4

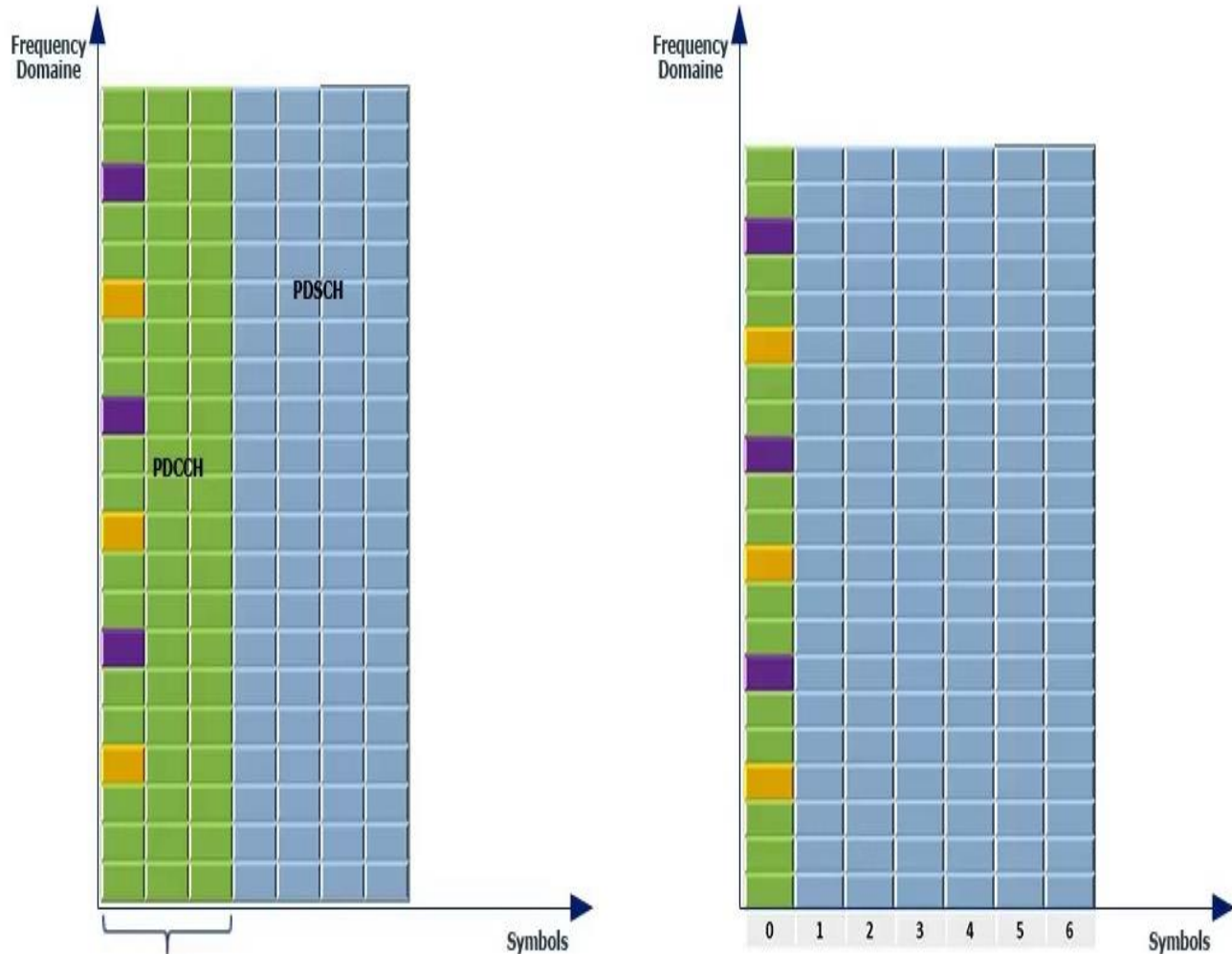


CCE Unused CCE REs not assigned to CCE as not enough REs to create a CCE

Huawei Features

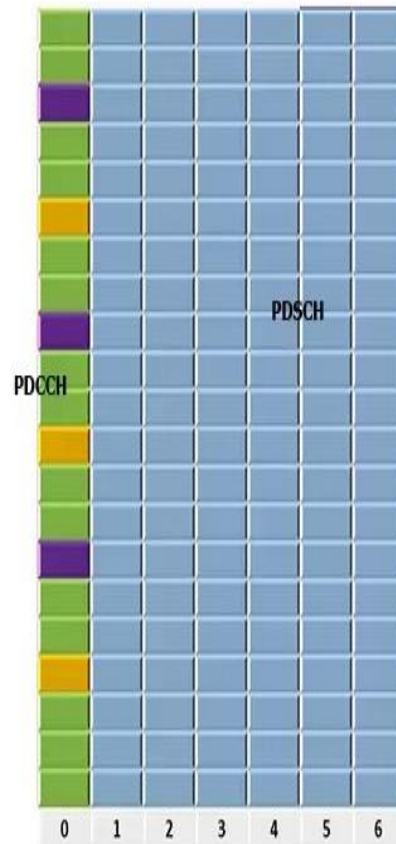
PDCCH Symbol Adaption

- Sometimes using 3 OFDM symbol for control region is redundant.
- For example when number of users is low , it is possible to send all three channels (PCFICH & PHICH & PDCCH) in single OFDM symbol. So it's better to reduce control region to 1 symbol and allocate 2 symbols to PDSCH.
- On the other hand , during peak hours , 1 symbol is not enough for PDCCH and eNB needs to increase OFDM symbol to maximum possible symbols which is 3 symbols.
- PDCCH Symbol Adaption is a very basic feature in Huawei LTE adaptively changes control region size.



- When the switch is OFF , Size of control region is fix and determined by this parameter.

PDCCH Settings - Symbol Adaptation



CellPdcchAlgo.PdcchSymNumSwitch:

OFF, ON, ECFIADAPTIONON

Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4

Default: 1

- When the switch is ON , eNB makes decision based on CCE allocation failure

PDCCH Settings - Symbol Adaptation

- ⇒ Uplink scheduling CCEs transmit uplink grants.
- ⇒ Downlink scheduling CCEs transmit downlink scheduling allocations.

UL/DL CCEs
fails to be
allocated



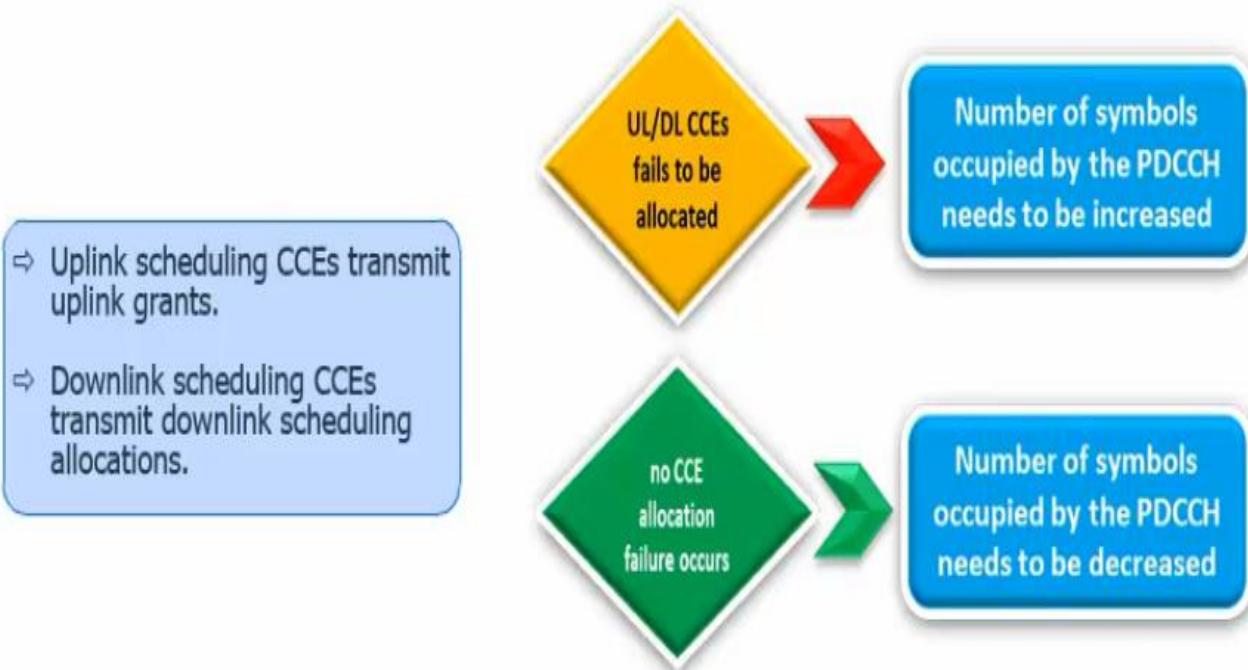
Number of symbols
occupied by the PDCCH
needs to be increased

CellPdcchAlgo.PdcchSymNumSwitch:
OFF **ON** ECFIADAPTIONON
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1

- When the switch is ON , eNB just considers CCE allocation failure to make a decision

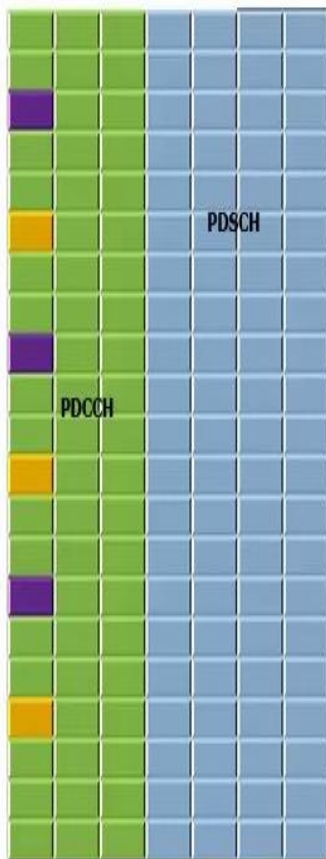
LTE Downlink Traffic: PDCCH Settings - Symbol Adaptation



CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, ECFIADAPTIONON
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1

PDCCH Settings - Symbol Adaptation



CellPdcchAlgo.PdcchSymNumSwitch:

OFF, ON, ECFIADAPTIONON

Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4

Default: 1

| CellPdcchAlgo.InitPdcchSymNum | CellPdcchAlgo.PdcchSymNumSwitch | Description |
|-------------------------------|---------------------------------|---|
| 1 | OFF | PDCCH uses only CFI=1 statically |
| 2 | | PDCCH uses only CFI=2 statically |
| 3 | | PDCCH uses only CFI=3 statically |
| 1 | On | if the bandwidth is 5 MHz, 10 MHz, 15 MHz, or 20 MHz, the eNodeB adjusts dynamically, PDCCH uses max CFI=3 dynamically. If the bandwidth is 1.4 MHz or 3 MHz, the PDCCH occupies 4 or 3 OFDM symbols, respectively. |
| 2 | | Dynamic adaptation up to CFI=2 |
| 3 | | Dynamic adaptation up to CFI=3 |

- In ECFIADAPTION mode , in addition to CCE Allocation failure , Load and scheduling type are considered.

PDCCH Settings - Symbol Adaptation

- Downlink load
- CCE load
- Scheduling type

⇒ ECfiAdaptionON increase slowly the number of Symbol occupied by the PDCCH and decrease it in a quicker manner.

CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, **ECFIADAPTIONON**
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1

PDCCH Settings - Symbol Adaptation

- Downlink load
- CCE load
- Scheduling type

⇒ ECfiAdaptionON increase slowly the number of Symbol occupied by the PDCCH and decrease it in a quicker manner.

CCE allocation
fails for downlink
scheduling

The number of symbols
will not be increased

DL load > 90%

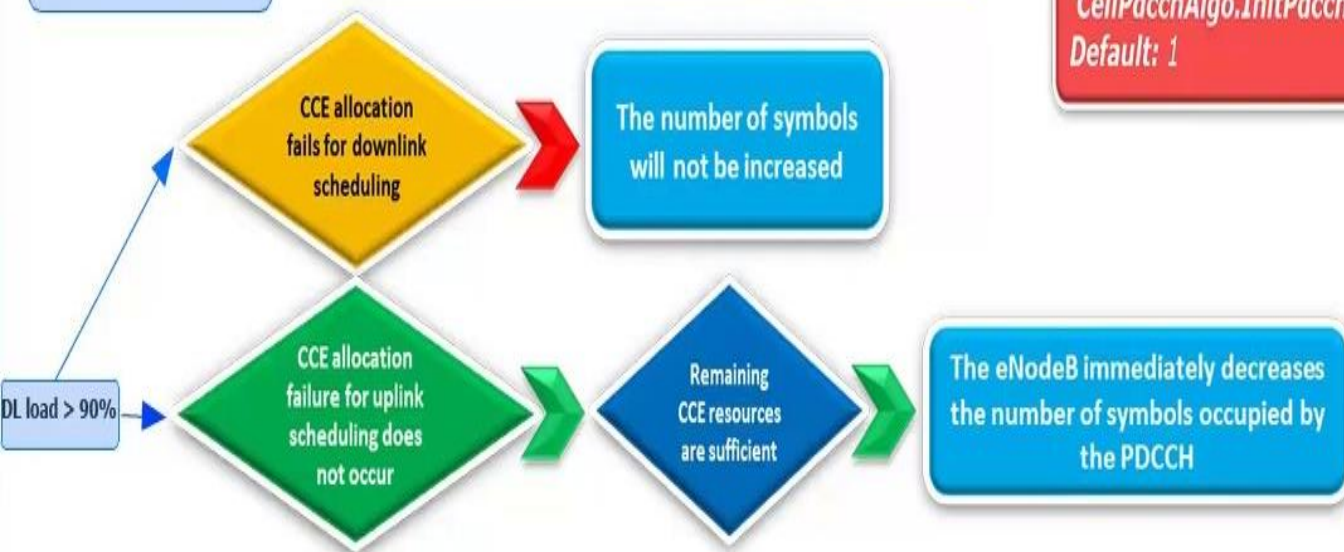
CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, **ECFIADAPTIONON**
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1

PDCCH Settings - Symbol Adaptation

- Downlink load
- CCE load
- Scheduling type

⇒ ECfiAdaptionON increase slowly the number of Symbol occupied by the PDCCH and decrease it in a quicker manner.



CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, **ECFIADAPTIONON**
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1

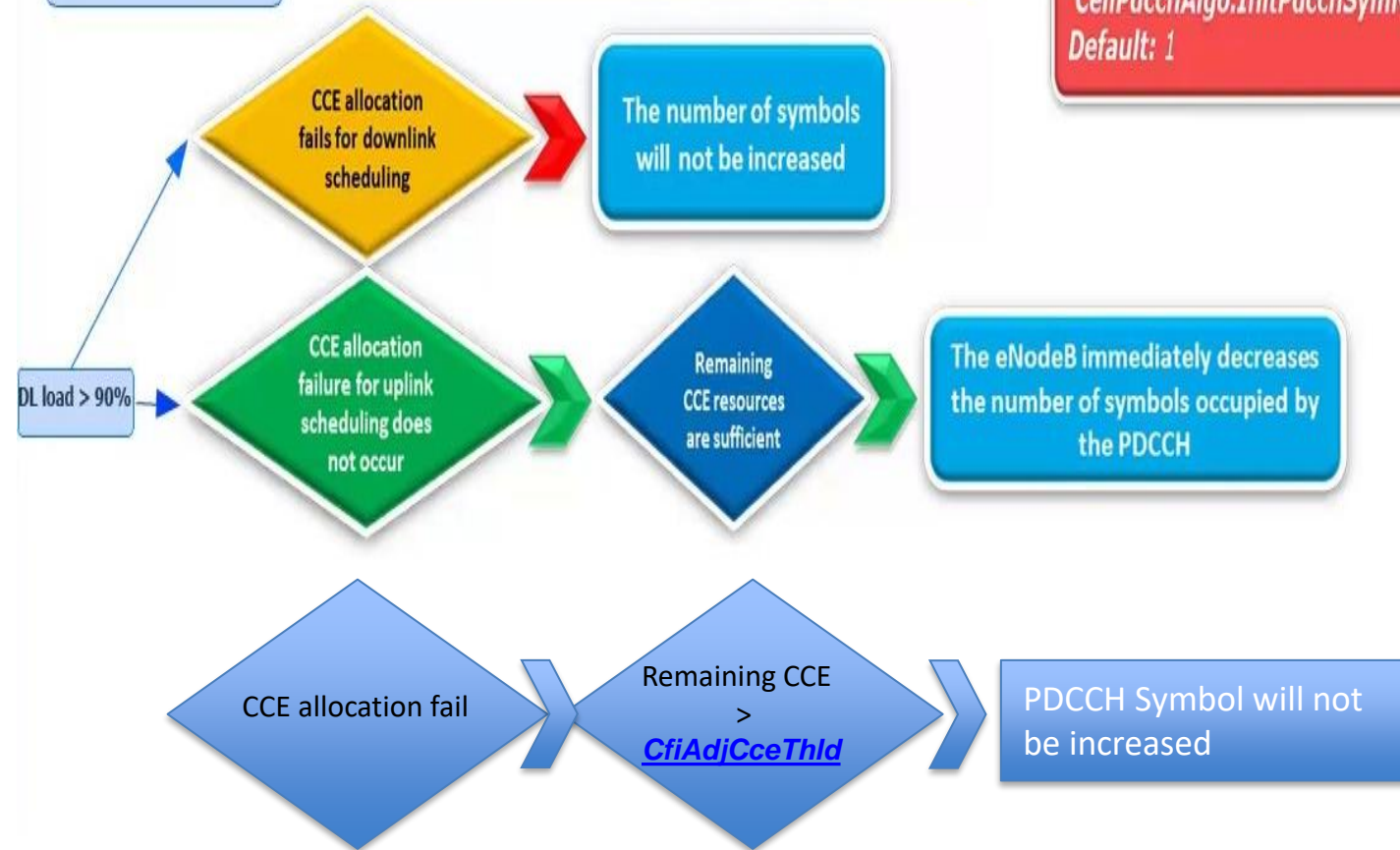
PDCCH Settings - Symbol Adaptation

- Downlink load
- CCE load
- Scheduling type

⇒ ECfiAdaptionON increase slowly the number of Symbol occupied by the PDCCH and decrease it in a quicker manner.

CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, **ECFIADAPTIONON**
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1



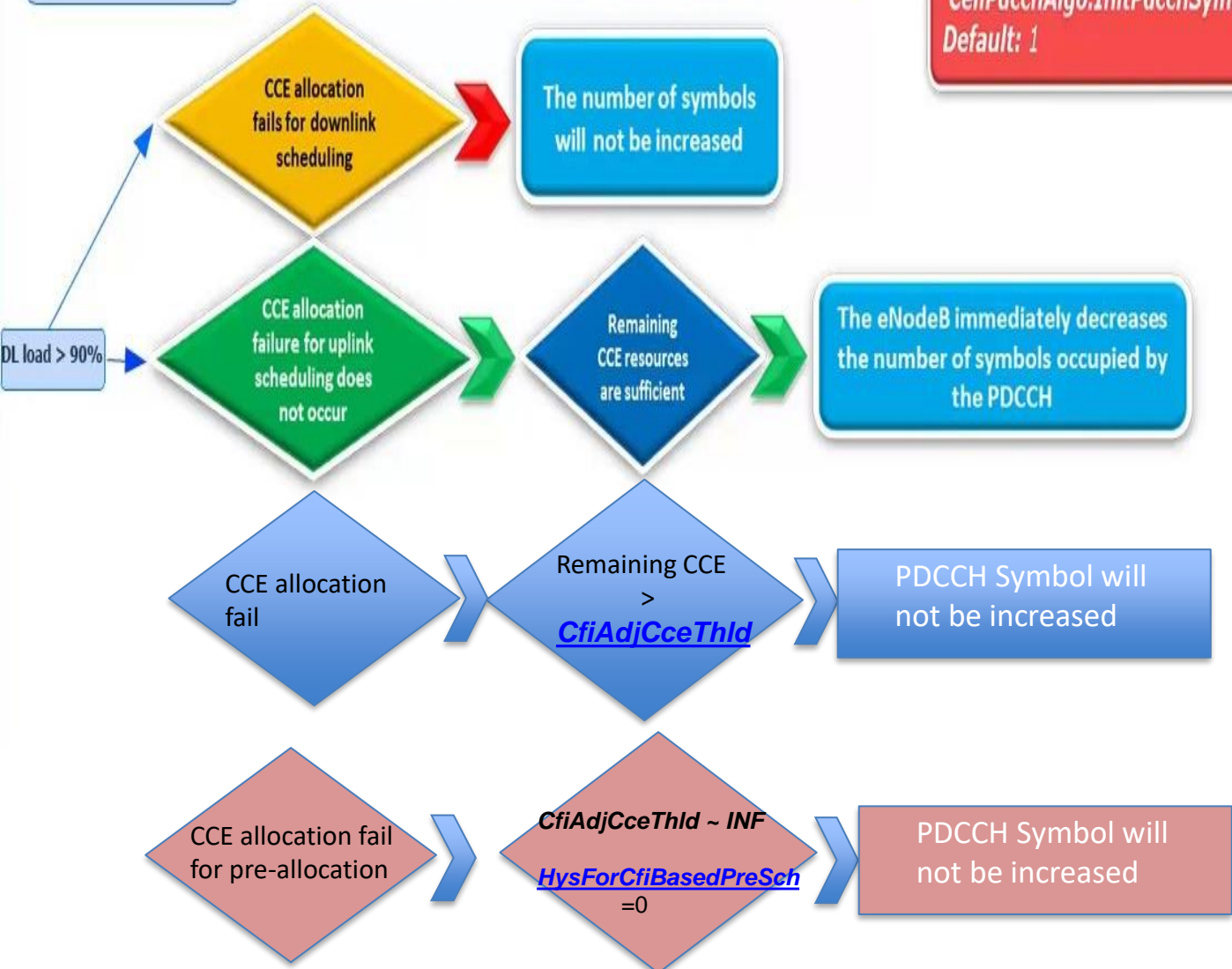
PDCCH Settings - Symbol Adaptation

- Downlink load
- CCE load
- Scheduling type

⇒ ECfiAdaptionON increase slowly the number of Symbol occupied by the PDCCH and decrease it in a quicker manner.

CellPdcchAlgo.PdcchSymNumSwitch:
OFF, ON, **ECFIADAPTIONON**
Default: ECFIADAPTIONON

CellPdcchAlgo.InitPdcchSymNum: 1~4
Default: 1



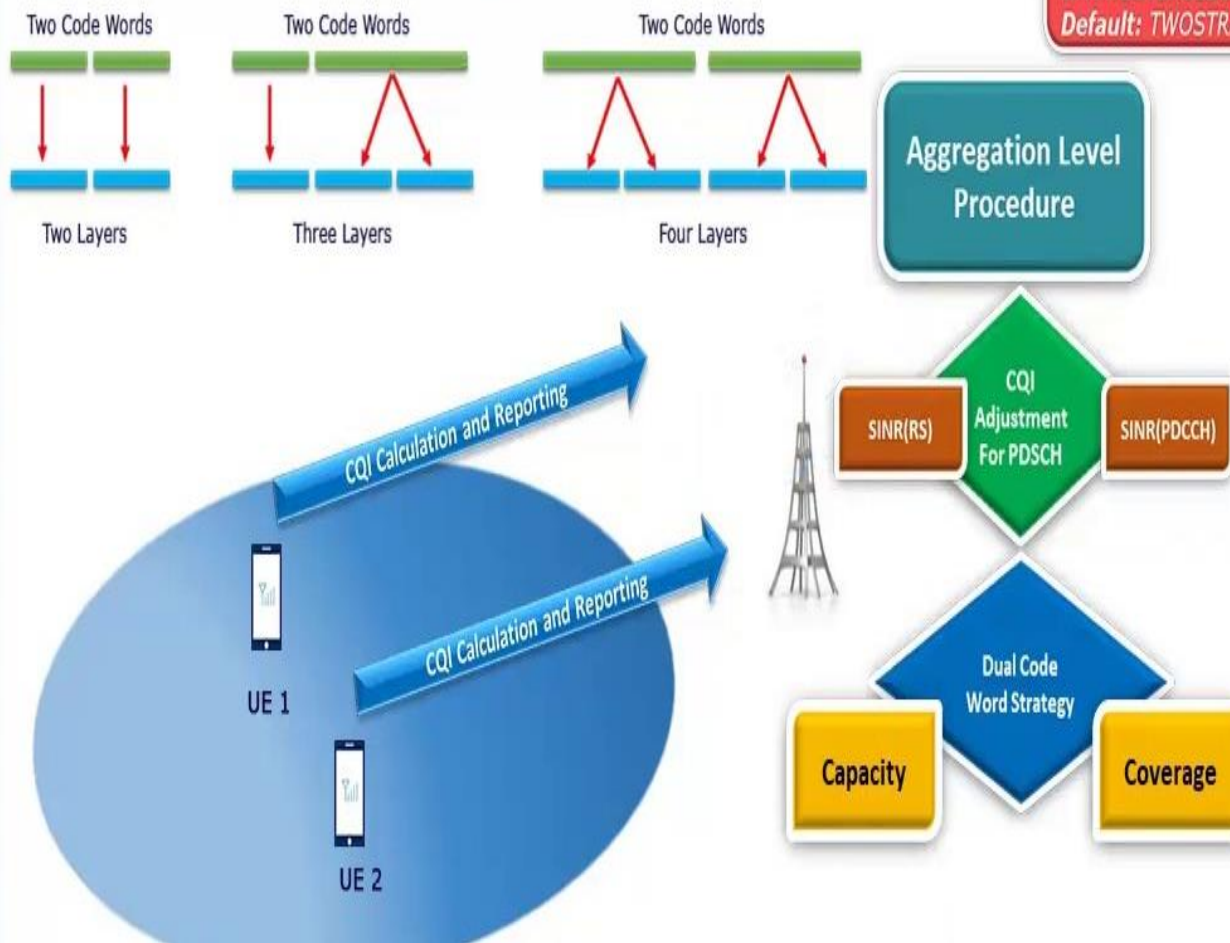
Huawei Features

PDCCH aggregation level in
dual-codeword scenarios

LTE Downlink Traffic: PDCCH Settings - PDCCH Aggregation Level Adaptation

PDCCH aggregation level adaptation Procedure

CellPdcchAlgo.AggLvSelStrageForDualCW:
TWOSTRATEGYBASEDONCAPACITY,
STRATEGYBASEDONCOVERAGE
Default: TWOSTRATEGYBASEDONCAPACITY



Huawei Features

maximum PDCCH code rate

Due to demodulation performance differences between UEs, the `CellPdcchAlgo.PdcchMaxCodeRate` parameter is introduced to set the maximum PDCCH code rate. When the PDCCH code rate exceeds the value of this parameter, the eNodeB raises the PDCCH aggregation level.

When this parameter is set to a smaller value, the eNodeB selects a higher PDCCH aggregation level, which leads to larger coverage but lower PDCCH capacity.

When this parameter is set to a larger value, the eNodeB selects a lower PDCCH aggregation level, which leads to smaller coverage but higher PDCCH capacity.

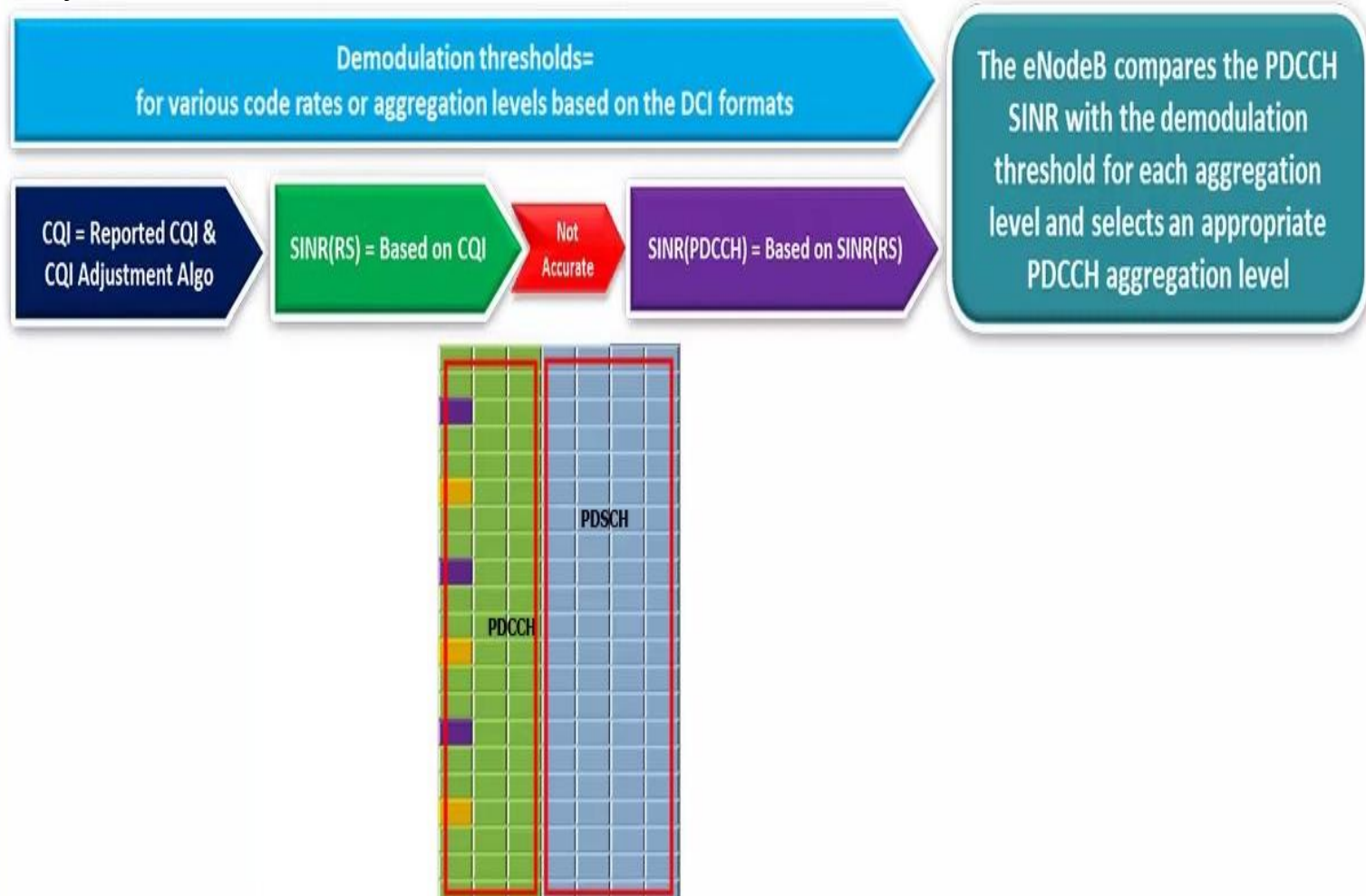
Closed-Loop Adjustment to the PDCCH Aggregation Level

eNB uses SINR of RS to estimate SINR of PDCCH and consequently calculate an appropriate Agg LVL

There are some reasons that may lead to inaccurate PDCCH SINR calculation.

- Delay in reported CQI can be greater than time coherence of channel.
- CQI adjustment algorithm imperfection

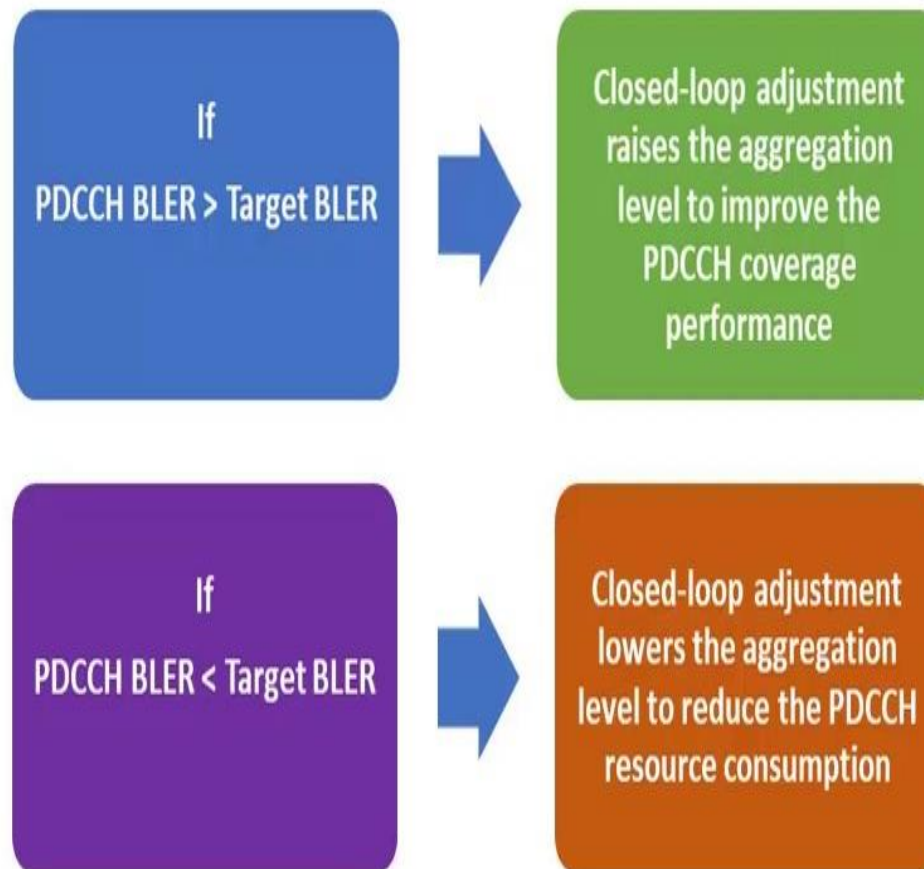
We need to adjust calculated AGG Level.



LTE Downlink Traffic: **PDCCH Settings** - Closed-Loop Adjustment to the PDCCH Aggregation Level

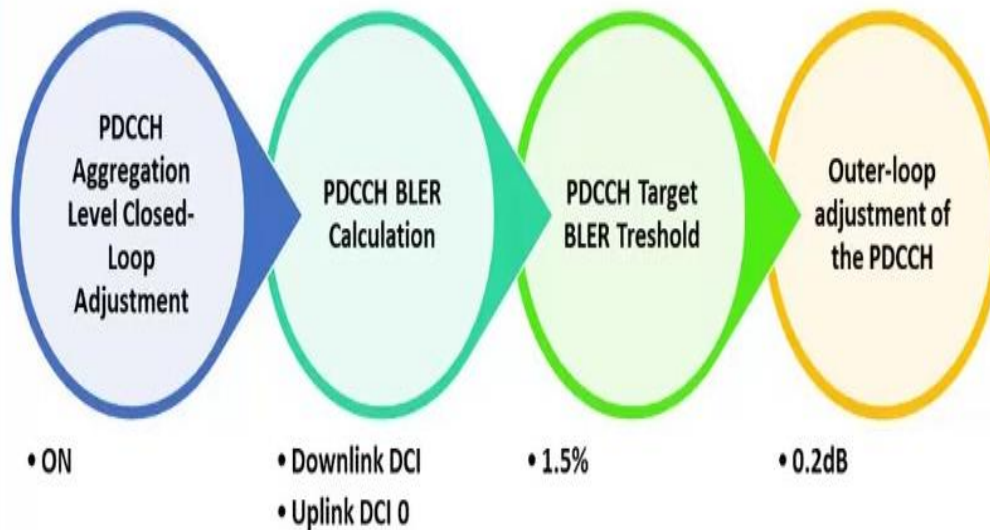


LTE Downlink Traffic: **PDCCH Settings** - Closed-Loop Adjustment to the PDCCH Aggregation Level



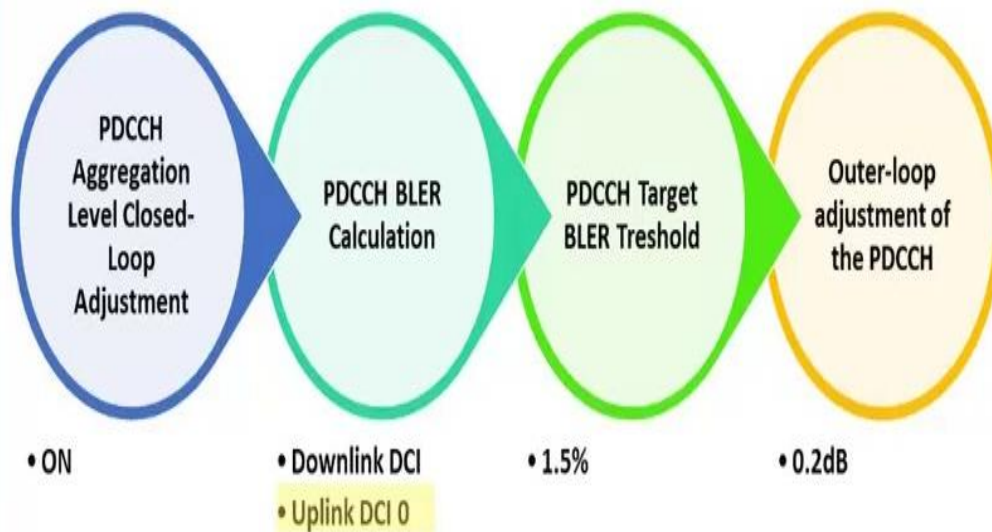
LTE Downlink Traffic: **PDCCH Settings** - Closed-Loop Adjustment to the PDCCH Aggreagation Level

CellPdcchAlgo.PdcchAggLvlCLAdjustSwitch:
OFF, ON
Default: ON



- PDCCH BLER can be calculated based on Uplink DCI0 or downlink DCIs

- If PUSCHDtxSwitch = ON → based on DCI0
- O.W → based on all downlink DCIs

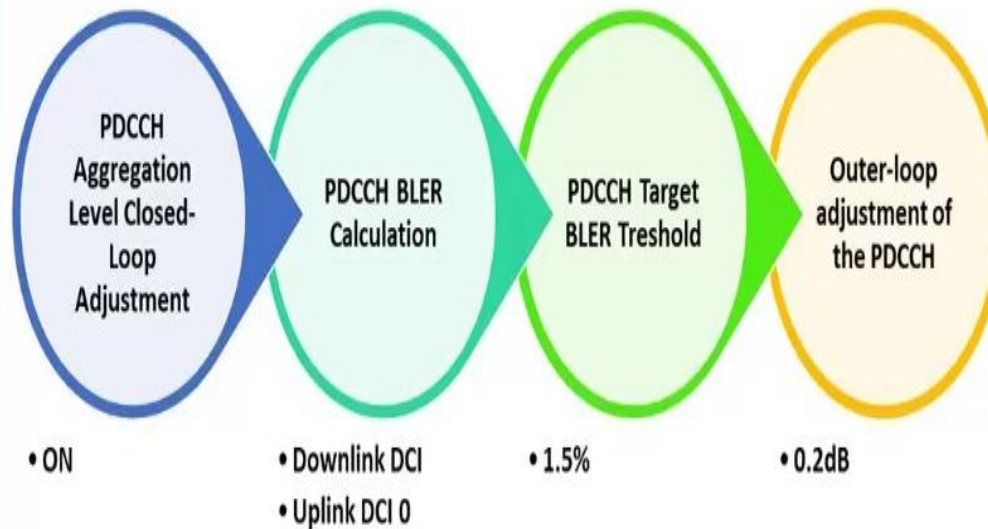


CellPdcchAlgo.PdcchAggLvlCLAdjustSwitch:
OFF, ON
Default: ON

CellAlgoSwitch.UISch: ✓ *PuschDtxSwitch*
Default: ON

- Target BLER = PdcchBlrTarget

LTE Downlink Traffic: **PDCCH Settings** - Closed-Loop Adjustment to the PDCCH Aggregation Level

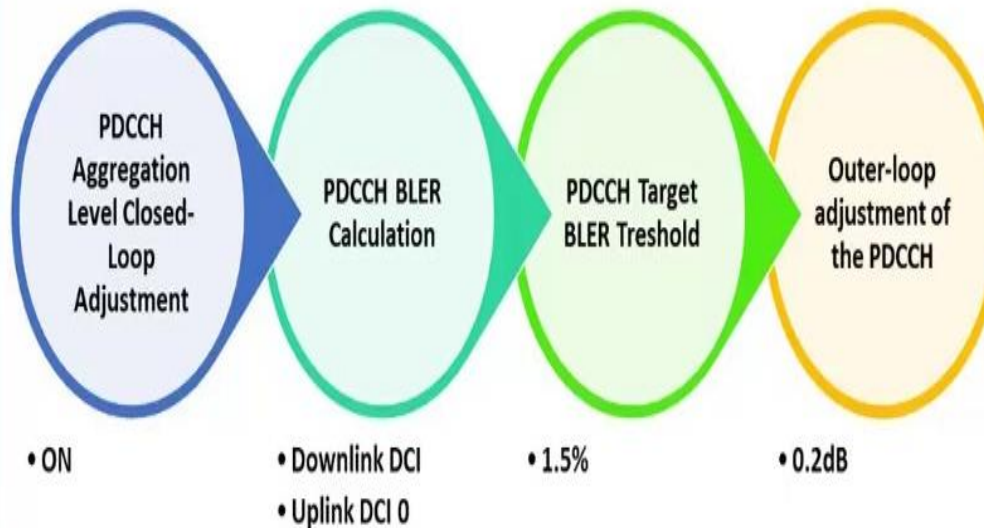


CellPdcchAlgo.PdcchAggLvICLAdjustSwitch:
OFF, ON
Default: ON

CellAlgoSwitch.UISch: ✓ PuschDtxSwitch
Default: ON

CellPdcchAlgo.PdcchBlrTarget(0.001):
1~1000
Default: 15

LTE Downlink Traffic: **PDCCH Settings** - Closed-Loop Adjustment to the PDCCH Aggregation Level



CellPdcchAlgo.PdcchAggLvlCLAdjustSwitch:
OFF, ON
Default: ON

CellAlgoSwitch.UISch: ✓ *PuschDtxSwitch*
Default: ON

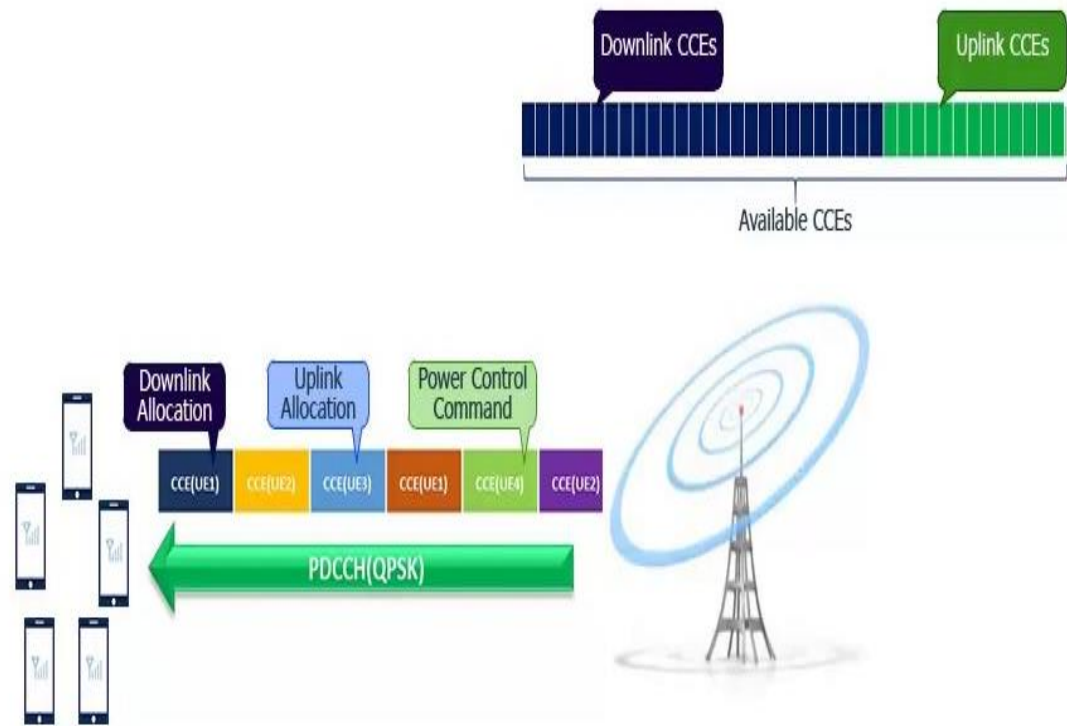
CellPdcchAlgo.PdcchBlerTarget(0.001):
1~1000
Default: 15

CellPdcchAlgo.PdcchOutLoopAdjBaseStep (0.1dB):
0~10
Default: 2

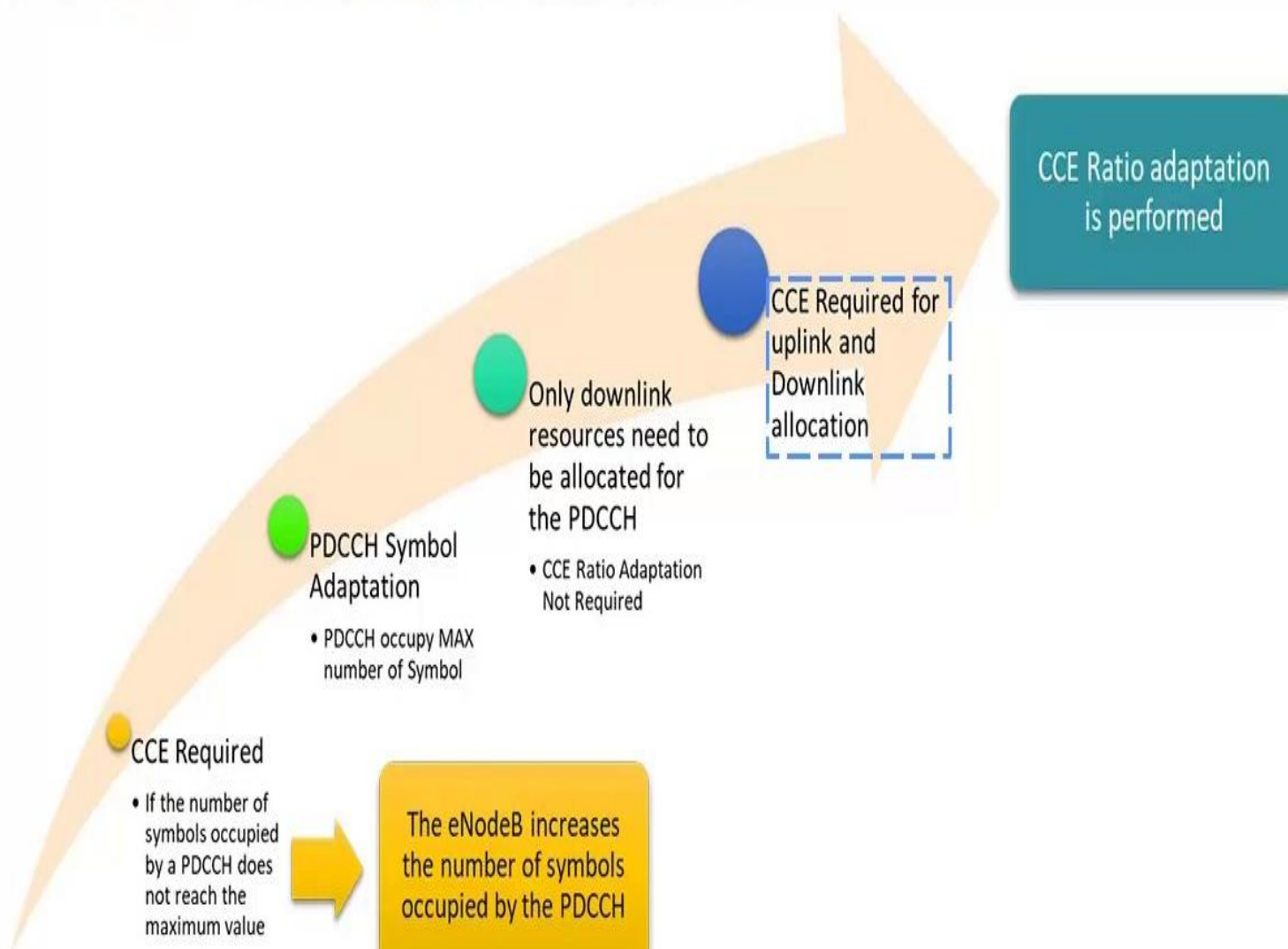
CCE RATIO Adjustment

Uplink CCEs transmit uplink grants, and downlink CCEs transmit downlink grants.
The CCE ratio is a ratio of the number of uplink CCEs to the number of downlink CCEs.

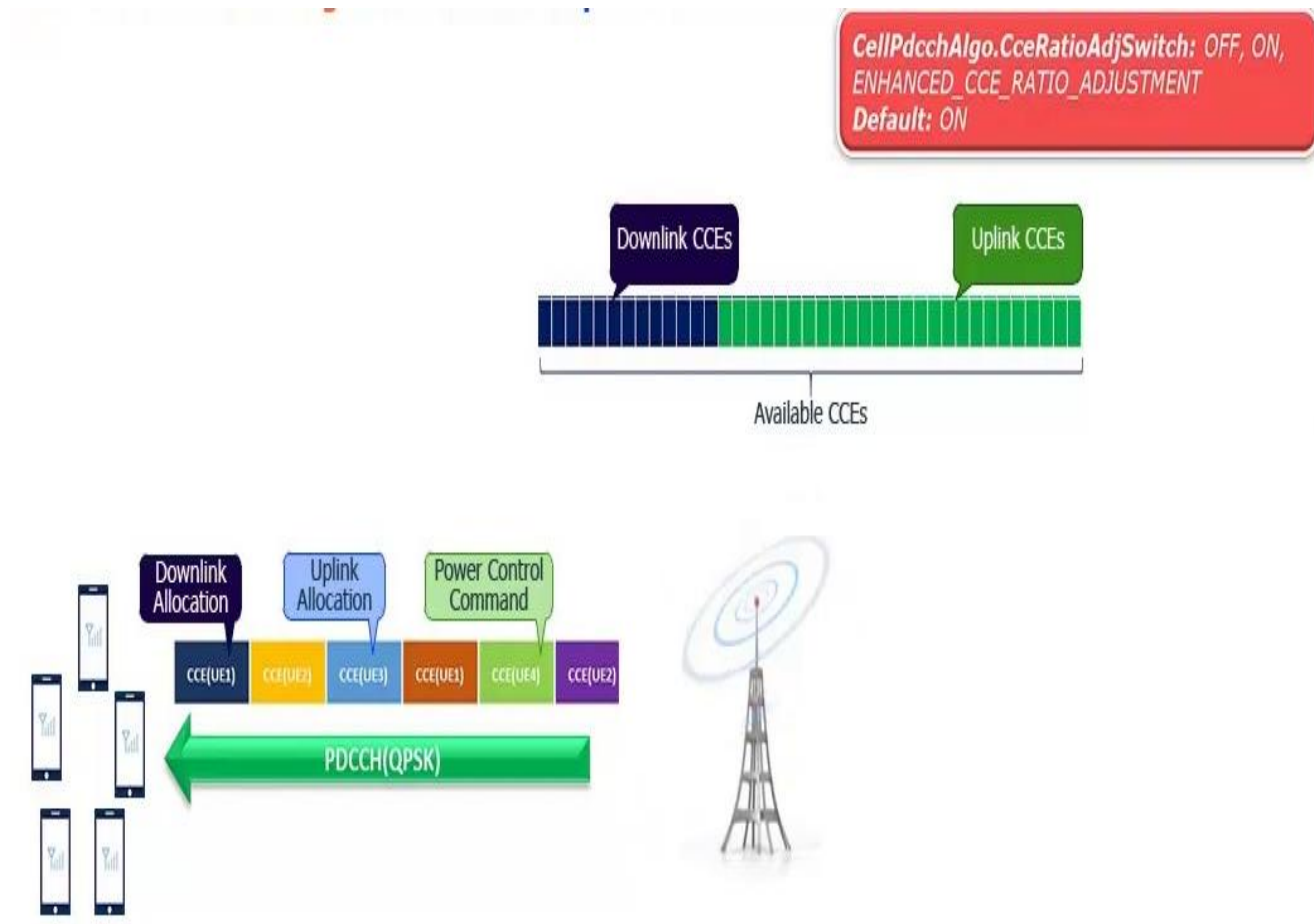
- Format 0:** Used for uplink PUSCH allocations.
- Format 1:** Used for type 0 or type 1 downlink PDSCH allocations. (Primary)
- Format 1A,1B,1C and 1D:** Used for downlink PDSCH allocations.(used only for virtual resource blocks and antenna precoding)
- Format 2 and 2A:** Used for type 0 or type 1 downlink PDSCH allocations in spatial multiplexing(multiple antenna) systems.
- Format 3 and 3A:** Used for PUCCH and PUSCH power adjustments.
- Format 4:** Used for the scheduling of PUSCH with multi-antenna port transmission mode.



LTE Downlink Traffic: PDCCH Settings - CCE Ratio Adaptation

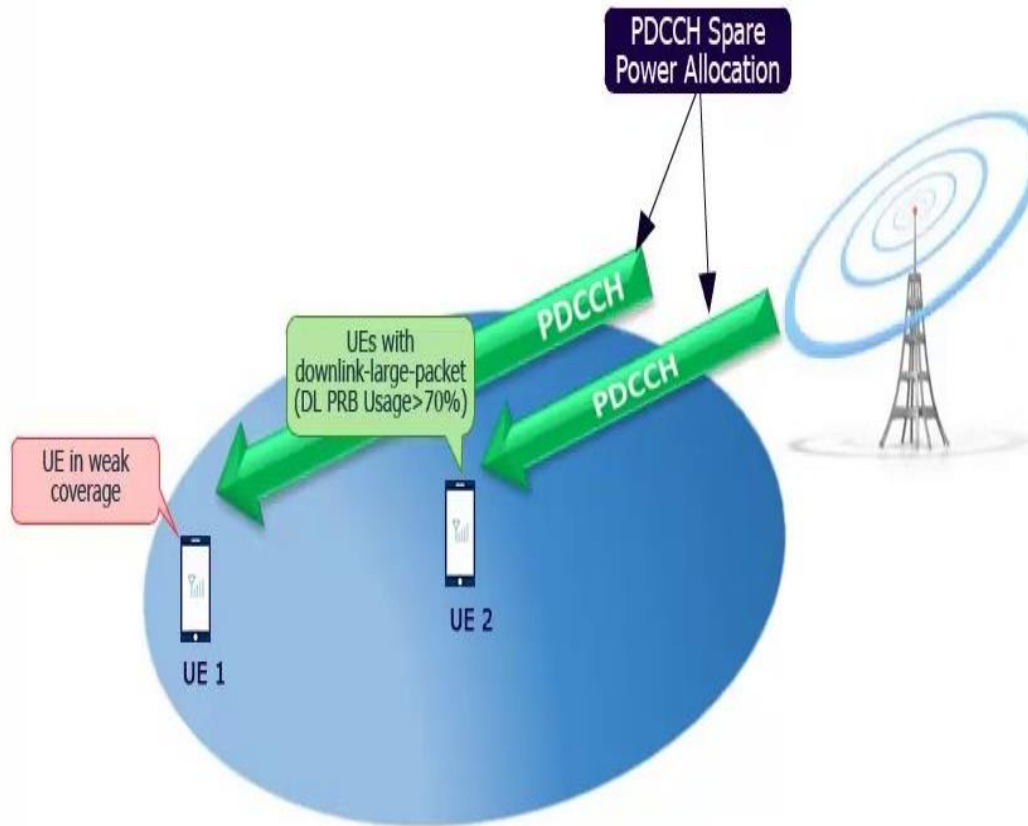


| | | |
|-------------------|-------------------------------|--|
| CceRatioAdjSwitch | OFF | The CCE ratio is always 2:3 in a 5-MHz cell and is always 1:2 in a cell with a bandwidth other than 5 MHz |
| | ON | dynamically adjusts the CCE ratio in each TTI based on the usage of uplink and downlink CCEs |
| | ENHANCED_CCE_RATIO_ADJUSTMENT | CCE ratio is not dynamically adjusted in the event of uplink CCE allocation failure not caused by CCE resource insufficiency |

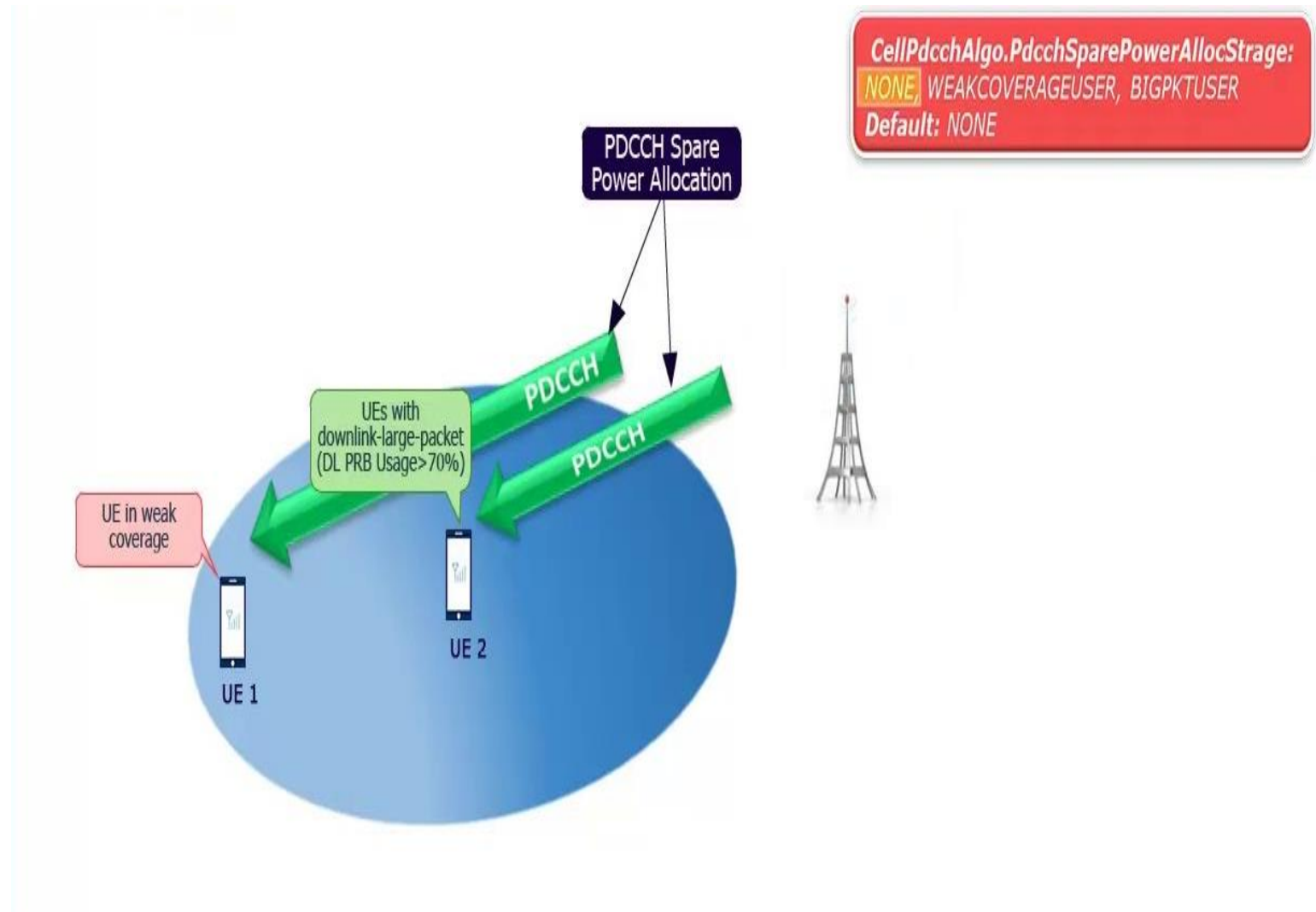


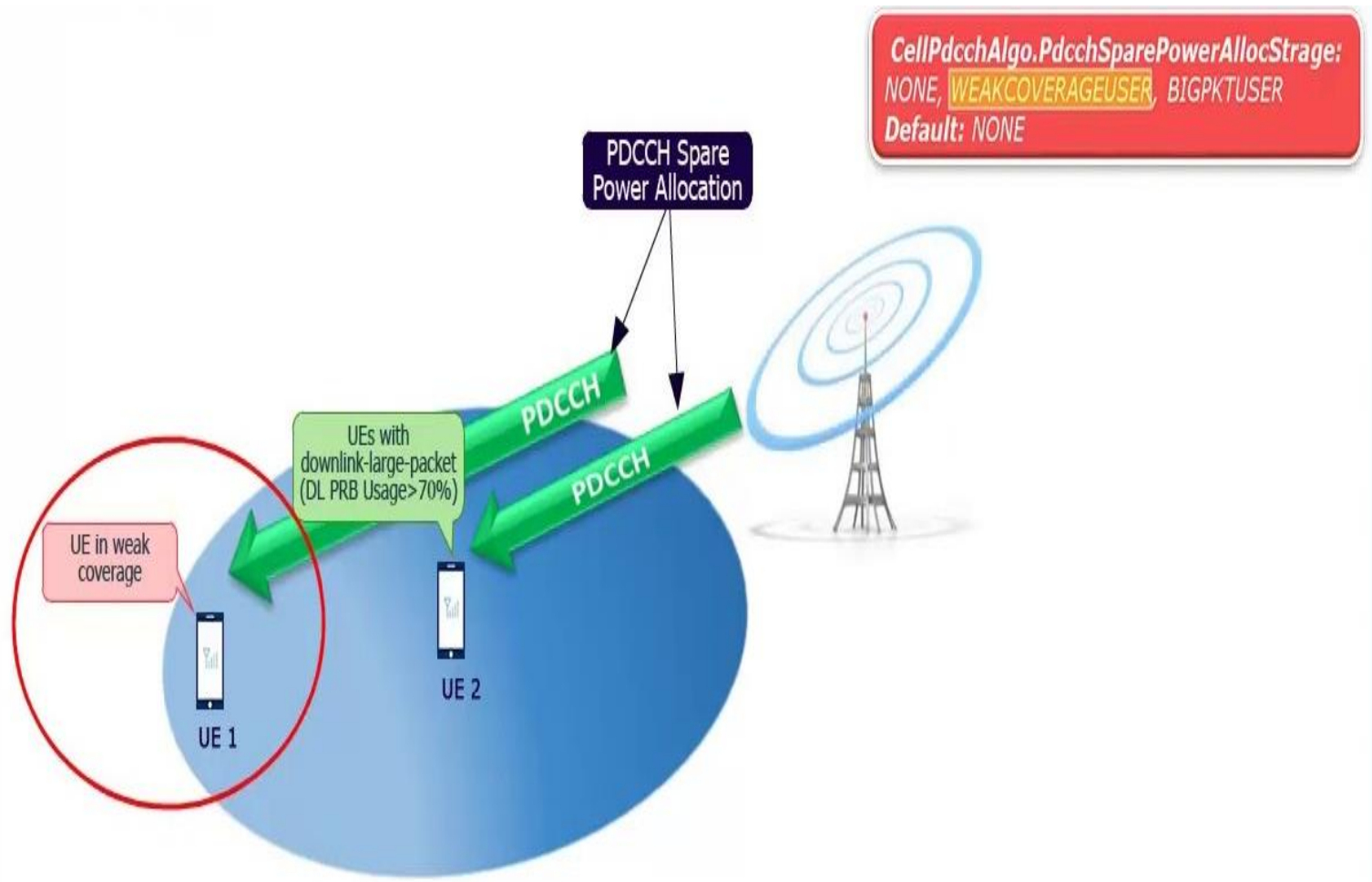
PDCCH Spare Power Allocation Optimization

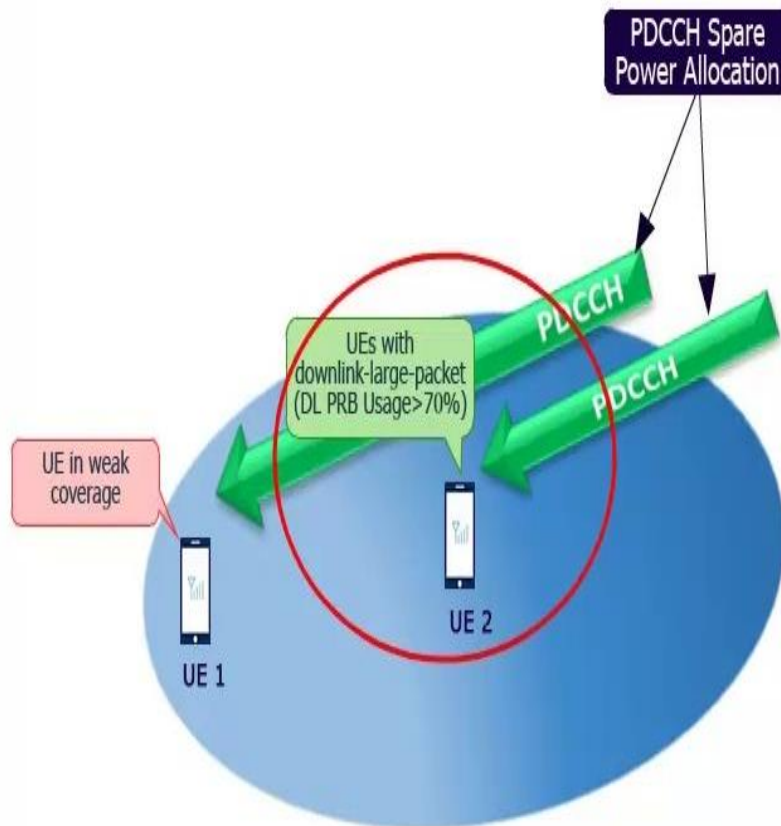
When PDCCH power resources are not used up, this function can allocate PDCCH spare power to UEs in areas with weak coverage or UEs with downlink-large-packet



When this parameter is set to NONE, this function does not allocate PDCCH spare power.

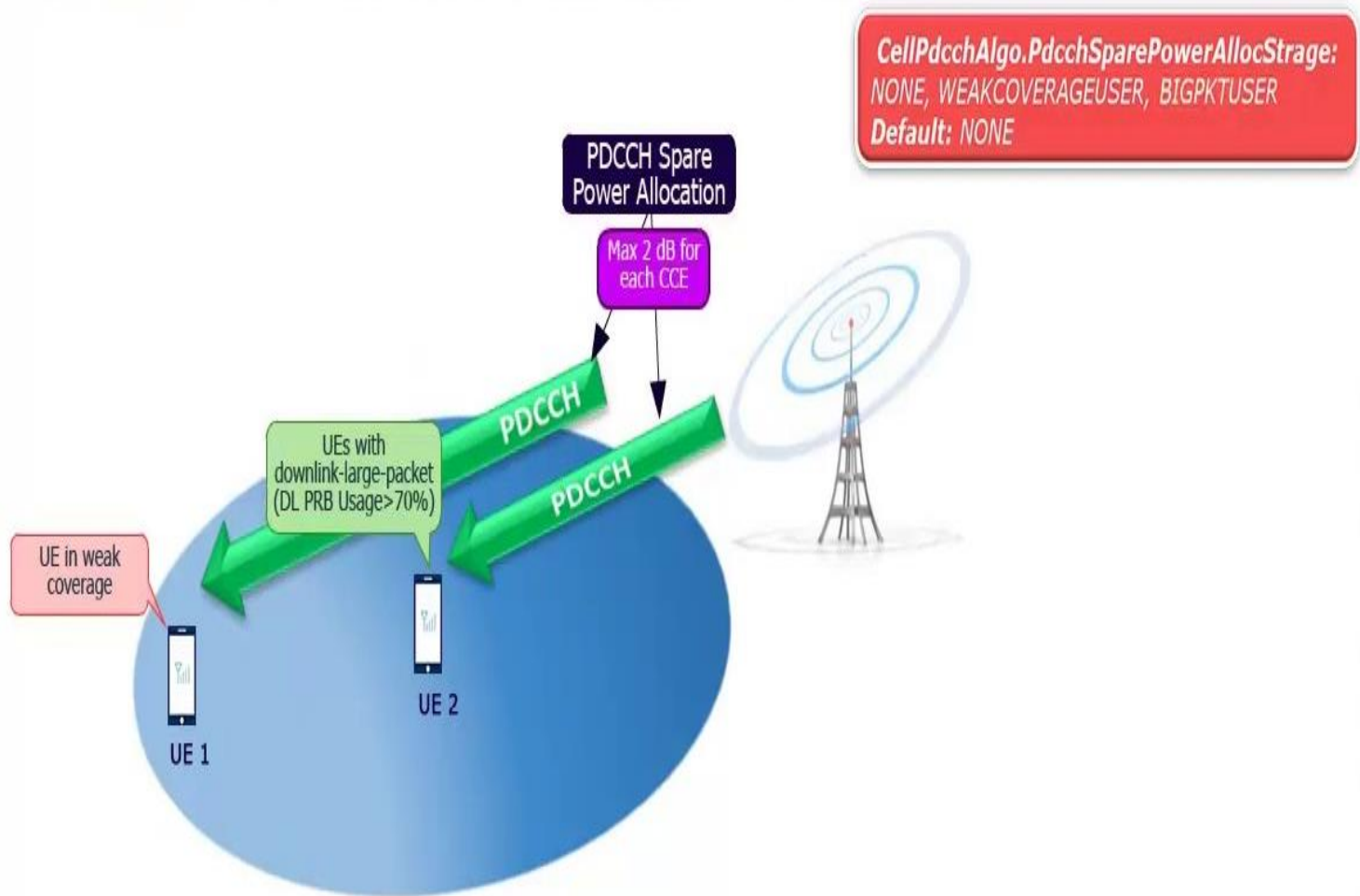






CellPdcchAlgo.PdcchSparePowerAllocStrage:
NONE, WEAKCOVERAGEUSER, **BIGPKTUSER**
Default: NONE

the upper limit of the power increased for each CCE cannot exceed 2 dB



Downlink PDCCH Power Control

LTE Downlink Traffic: PDCCH Optimization - Downlink PDCCH Power Allocation

- ⇒ The offset of the Power Allocation for PDCCH Carrying Common Control Information relative to the CRC power is always 0 dB.
- ⇒ The offset of the Power Allocation for PDCCH Carrying Dedicated Control Information relative to the CRC power is defined by the *CellDlpcPdcch.DediDciPwrOffset* parameter.

CellDlpcPdcch.DediDciPwrOffset(0.1dB):
-15~15
Default: -30

Control information:

- RACH responses
- paging messages
- system information blocks (SIBs)
- TPC commands using downlink control information (DCI) format 3

PDCCH Common Control Information

PDCCH Dedicated Control Information



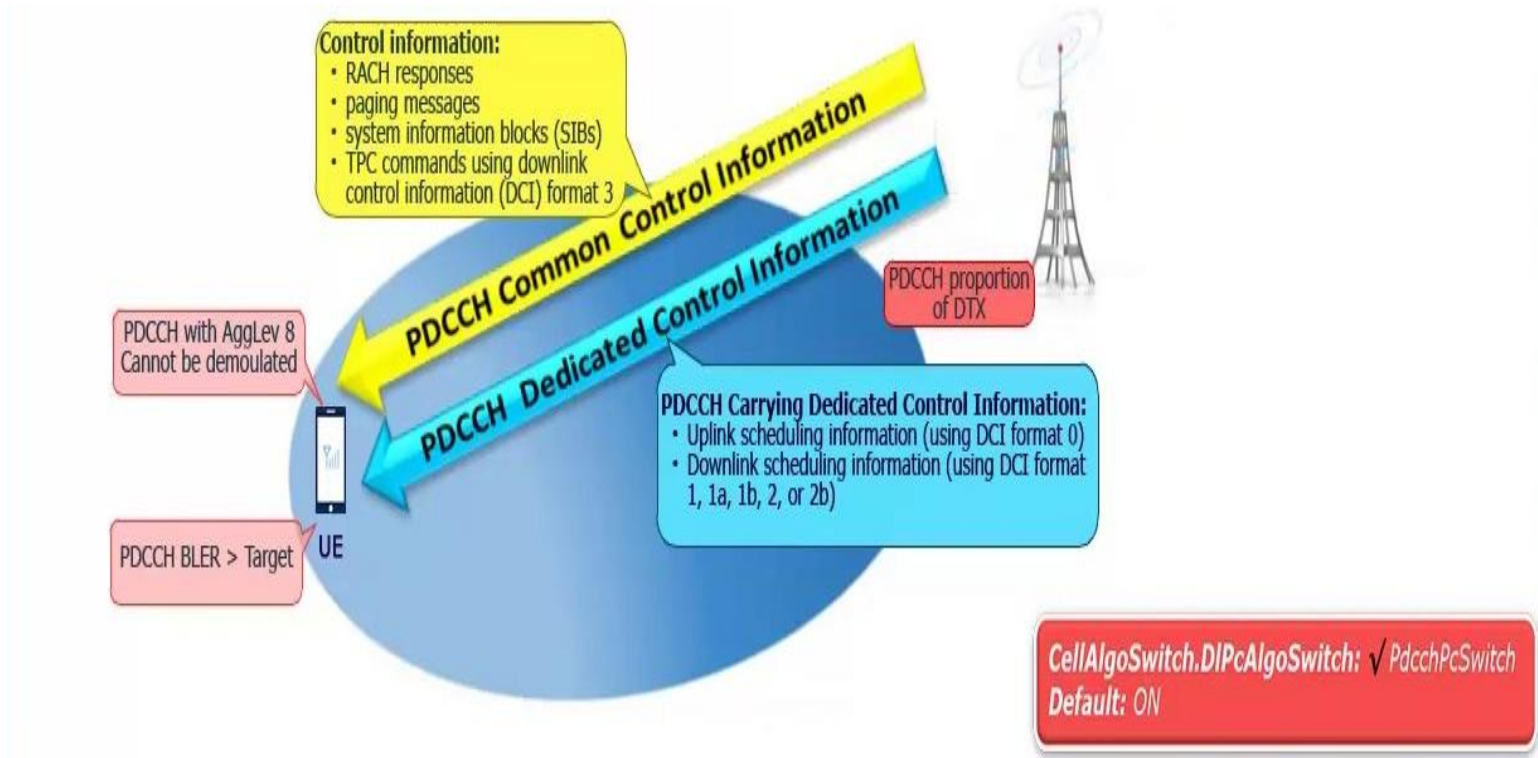
UE

PDCCH Carrying Dedicated Control Information:

- Uplink scheduling information (using DCI format 0)
- Downlink scheduling information (using DCI format 1, 1a, 1b, 2, or 2b)



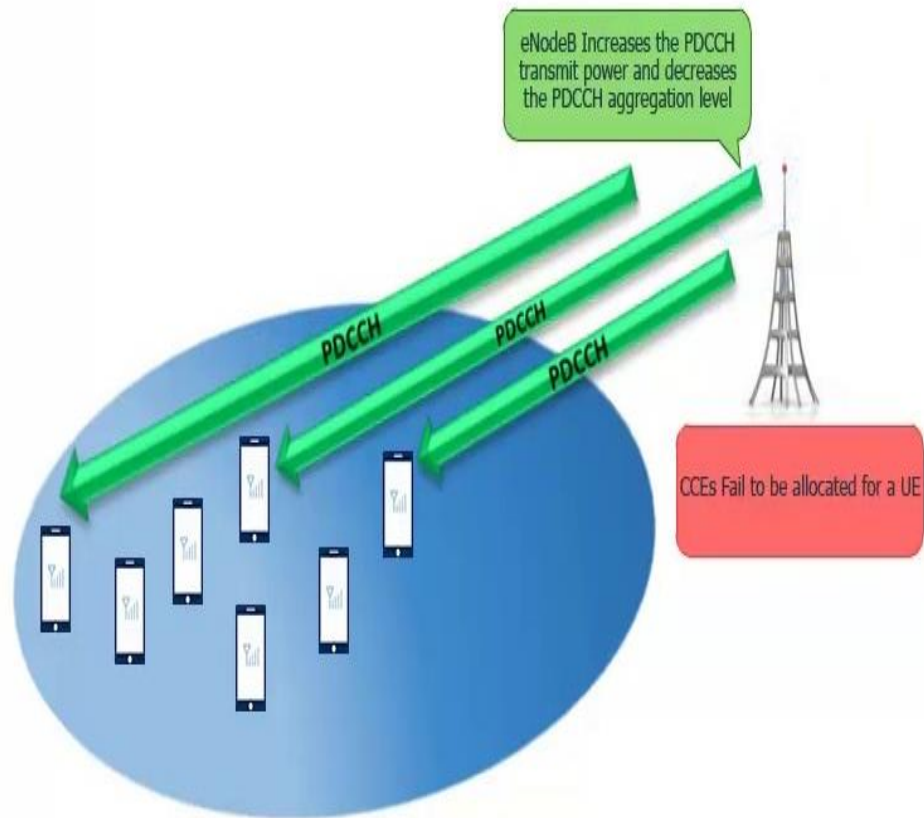
When the PDCCH BLER is greater than the target value, the eNodeB increases the CCE power.
When the PDCCH BLER is less than the target value, the eNodeB decreases the CCE power until it reaches the initial value.



PdcchCapacityImproveSwitch

PDCCH Capacity Improvement

CellPdcchAlgo.PdcchCapacityImproveSwitch:
ON OFF
Default: ON



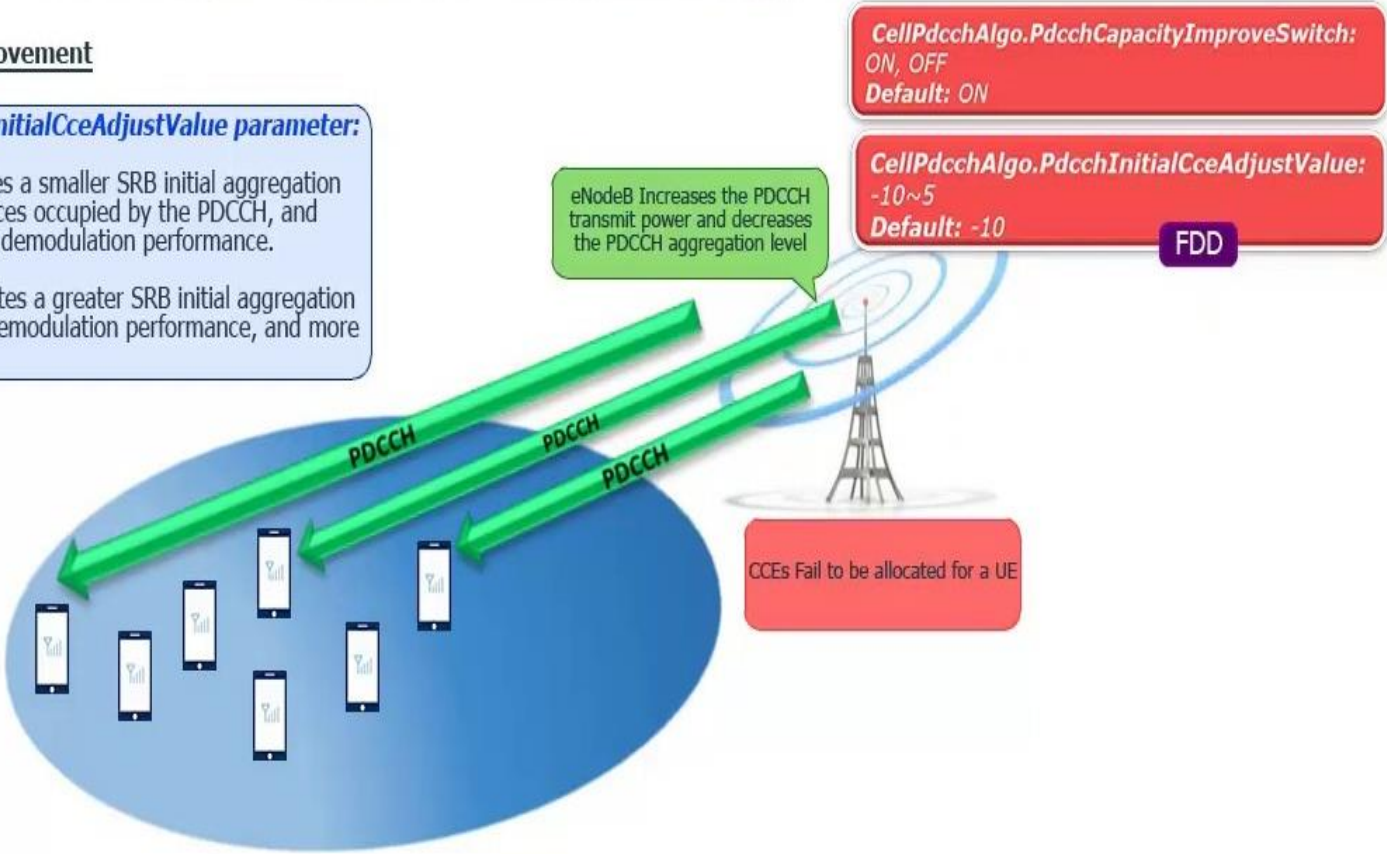
| PdcchCapacityImproveSwitch | PdcchInitialCceAdjustValue | Initial Agg Level for SRB | Initial Agg Level for DRB |
|----------------------------|----------------------------|----------------------------|----------------------------|
| ON | ≤ 0 | PdcchInitialCceAdjustValue | 0 |
| ON | > 0 | PdcchInitialCceAdjustValue | PdcchInitialCceAdjustValue |
| OFF | - | PdcchInitialCceAdjustValue | PdcchInitialCceAdjustValue |

LTE Downlink Traffic: **PDCCH Optimization** - PDCCH Utilization Improvement

PDCCH Capacity Improvement

⇒ **CellPdcchAlgo.PdcchInitialCceAdjustValue** parameter:

- A larger value indicates a smaller SRB initial aggregation level, less CCE resources occupied by the PDCCH, and slightly worse PDCCH demodulation performance.
- A smaller value indicates a greater SRB initial aggregation level, better PDCCH demodulation performance, and more occupied CCEs.

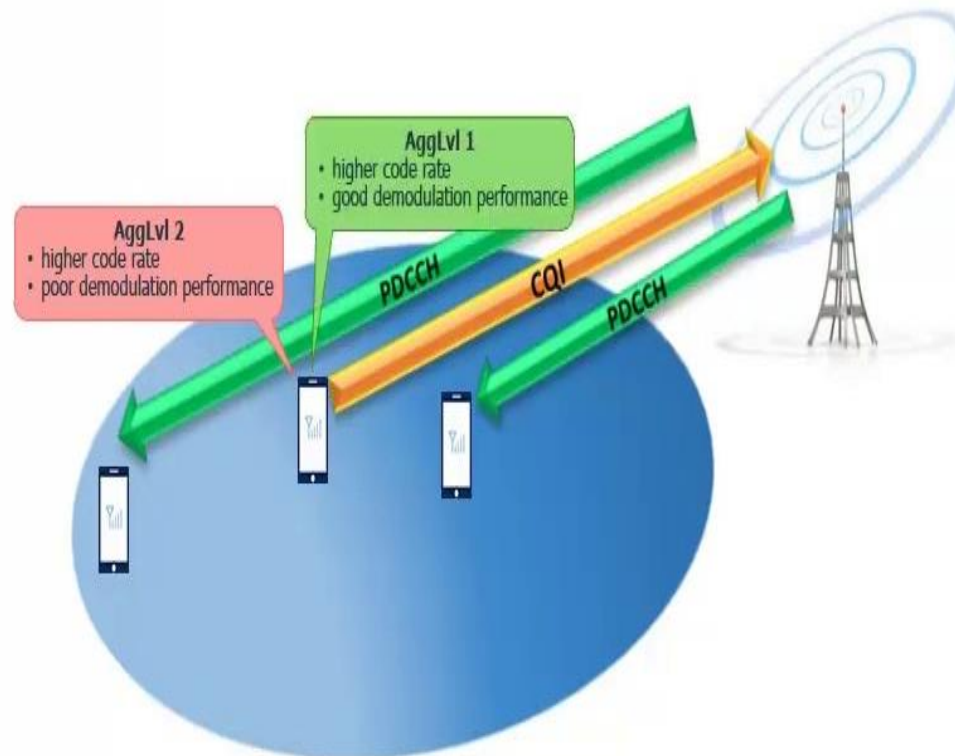


PDCCH power control improvement

For example in this picture , before activation, required Agg level is 2.
After activation, eNB reduces Agg level but allocates more power for UE.

PDCCH Power Control Improvement

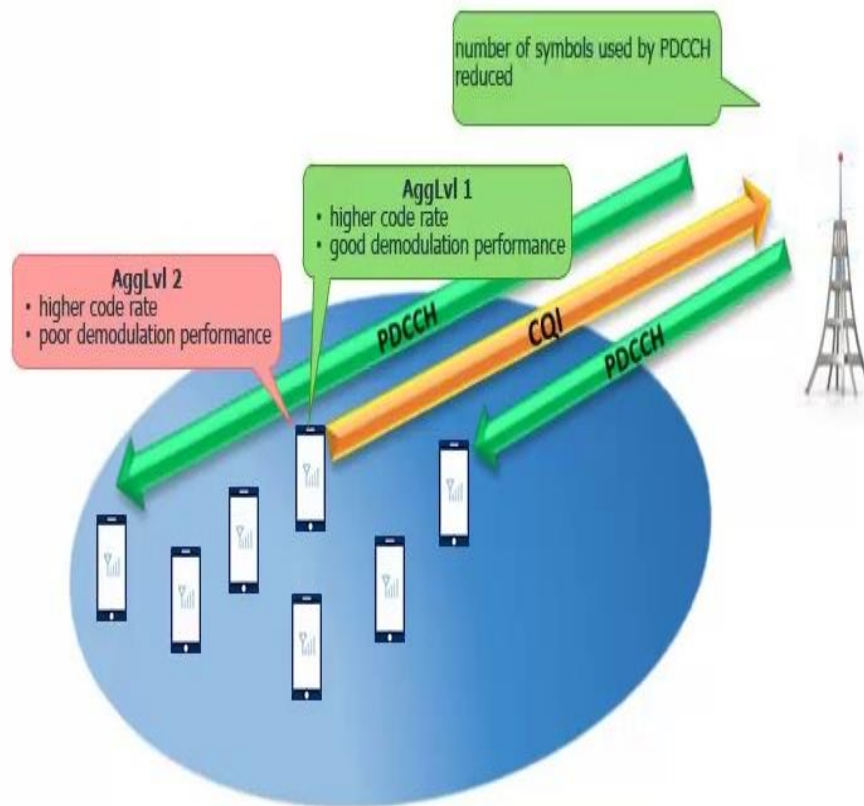
*CellPdcchAlgo.PdcchPowerEnhancedSwitch: OFF,
ON_ALL, ON_EXPANDED_RANGE, ON_BASIC_RANGE
Default: OFF*



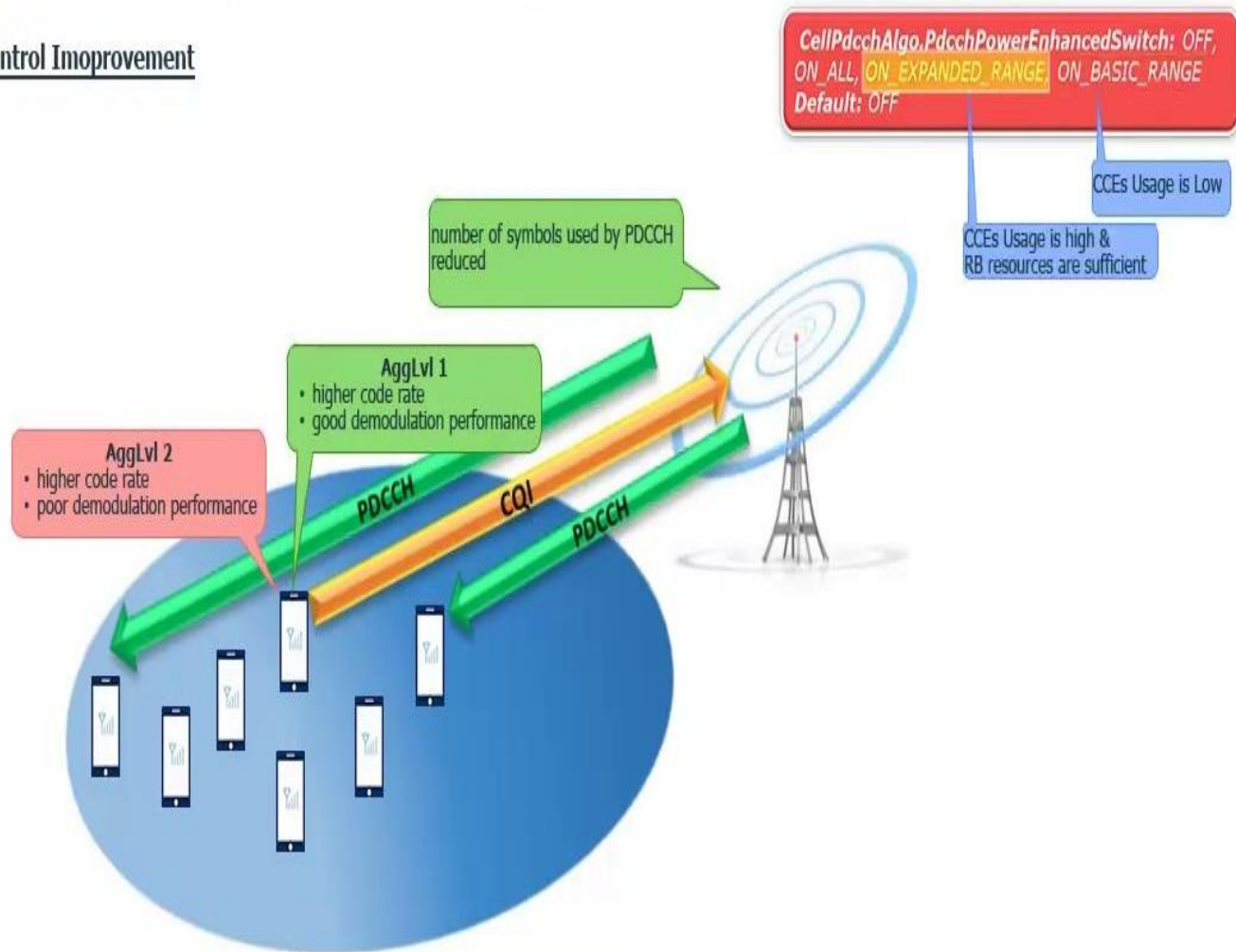
As a result, eNB can schedule more UEs.

PDCCH Power Control Improvement

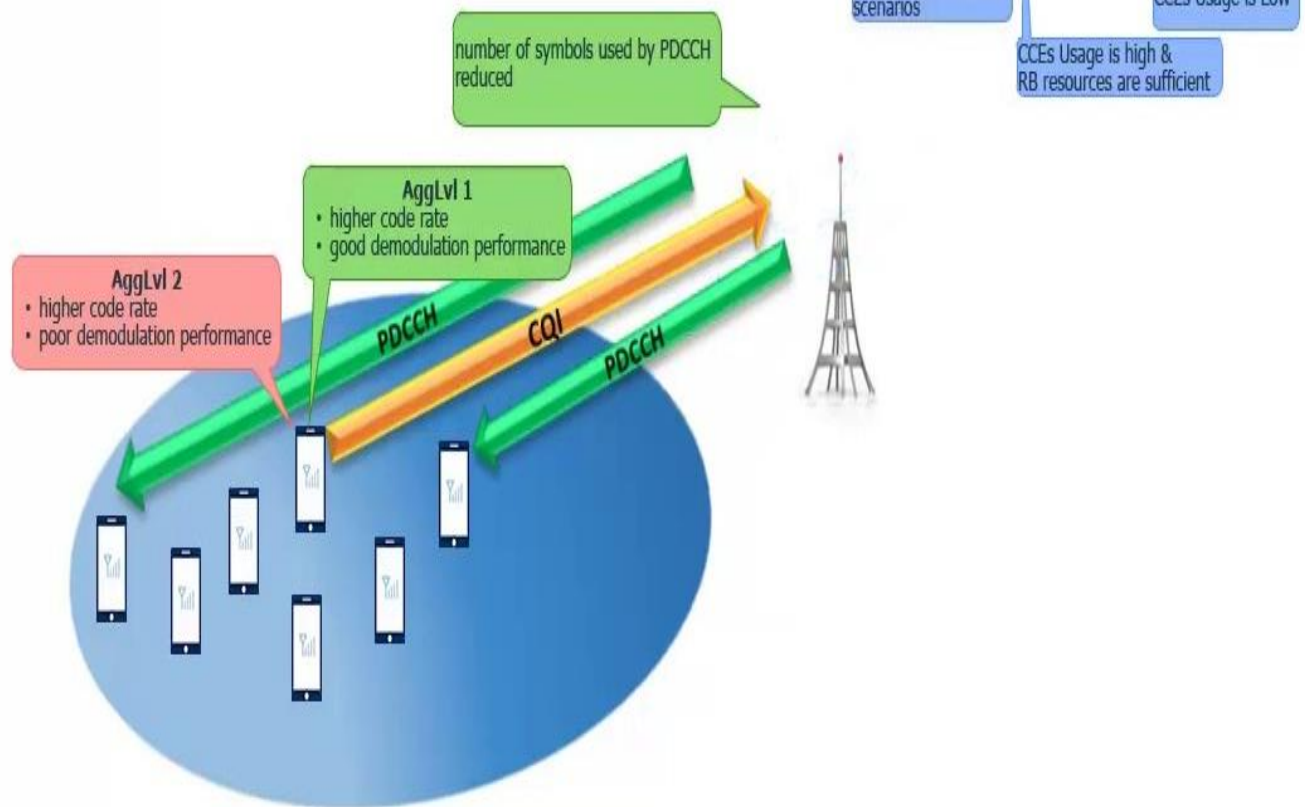
*CellPdcchAlgo.PdcchPowerEnhancedSwitch: OFF,
ON_ALL, ON_EXPANDED_RANGE, ON_BASIC_RANGE
Default: OFF*



PDCCH Power Control Improvement



PDCCH Power Control Improvement



PDCCH Power Control Improvement

