Resource Allocation in LTE

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Outline

Resources in LTE

Resource Grid, Resource Block, Slot, Sub-frame

Control Information

Physical Channels, PDCCH, DCI

Resource Allocation

Resource Block Group (RBG) based

RBG Subset based

Virtual Resource Block (VRB)-based

References

Resource in LTE

Resource in LTE

- **Resource**

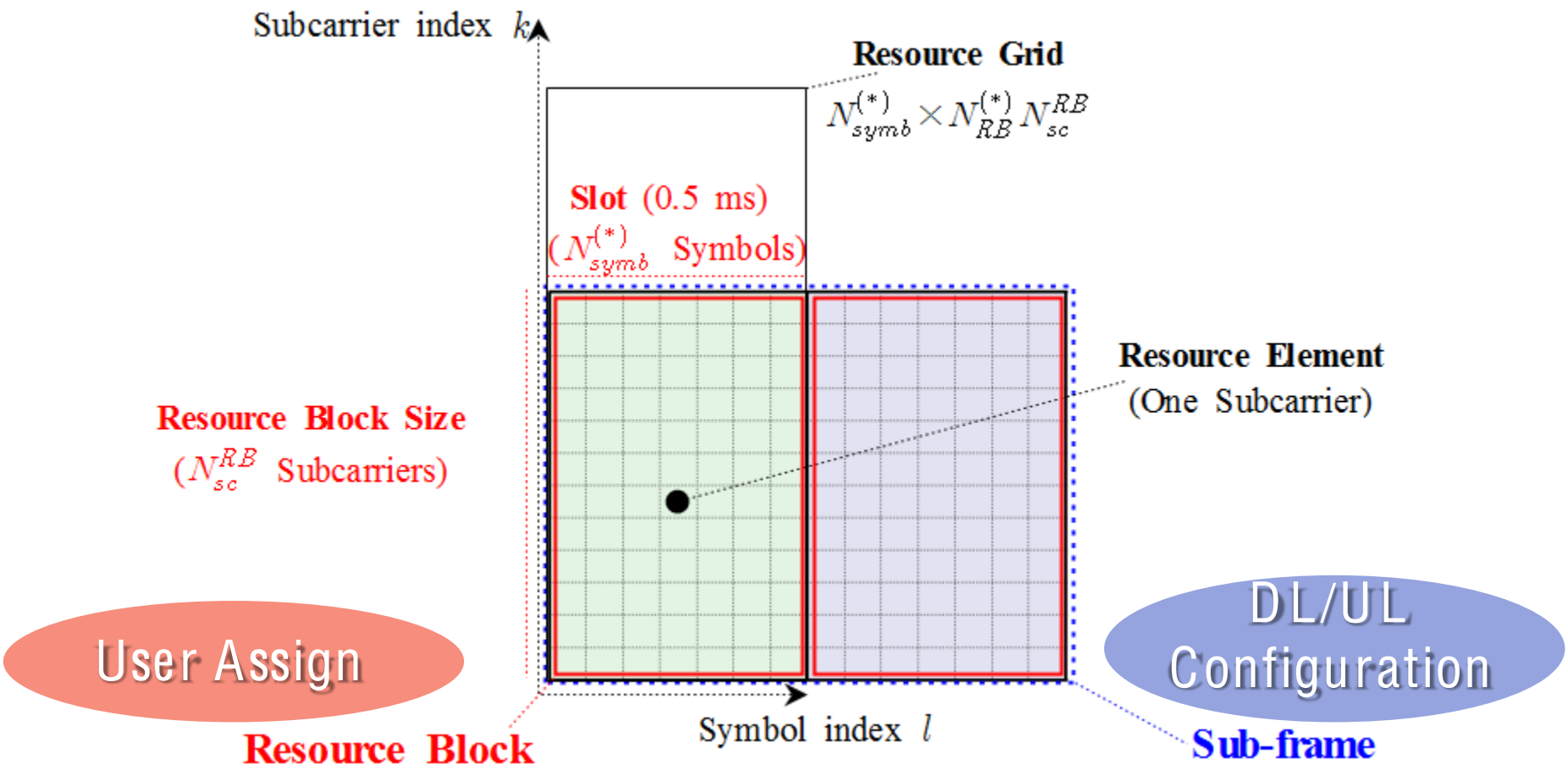
  ✓ **Used Subcarriers**

System BW [MHz]	1.4	3	5	10	15	20
Resource Blocks N_{RB}^{*}	6	15	25	50	75	100
FFT Size N ($\Delta f = 15KHz$ / $\Delta f = 7.5KHz$)	2048 / 4096					
Subcarriers per RB N_{sc}^{RB} ($\Delta f = 15KHz$ / $\Delta f = 7.5KHz$)	12 / 24					
Used Subcarriers N_u ($\Delta f = 15KHz$ / $\Delta f = 7.5KHz$)	72 / 144	180 / 360	300 / 600	600 / 1200	900 / 1800	1200 / 2400

N_{RB}^{*} (N_{RB}^{UL} for UL, N_{RB}^{DL} for DL)

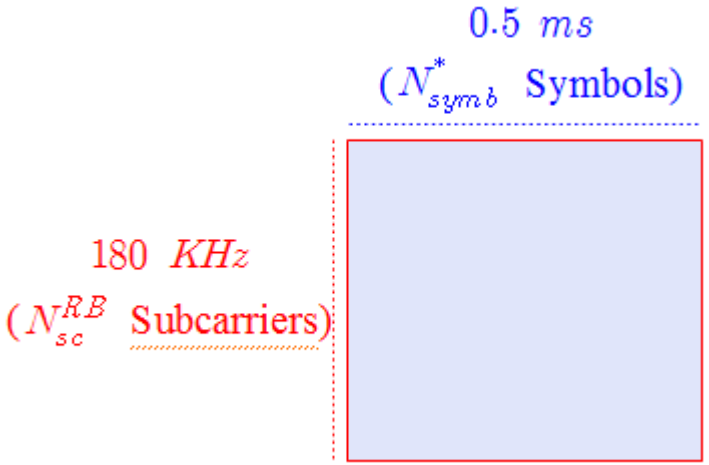
Resource Grid

- **Resource Grid, Slot, Sub-frame**



Resource Block

- **Resource Block Parameters**

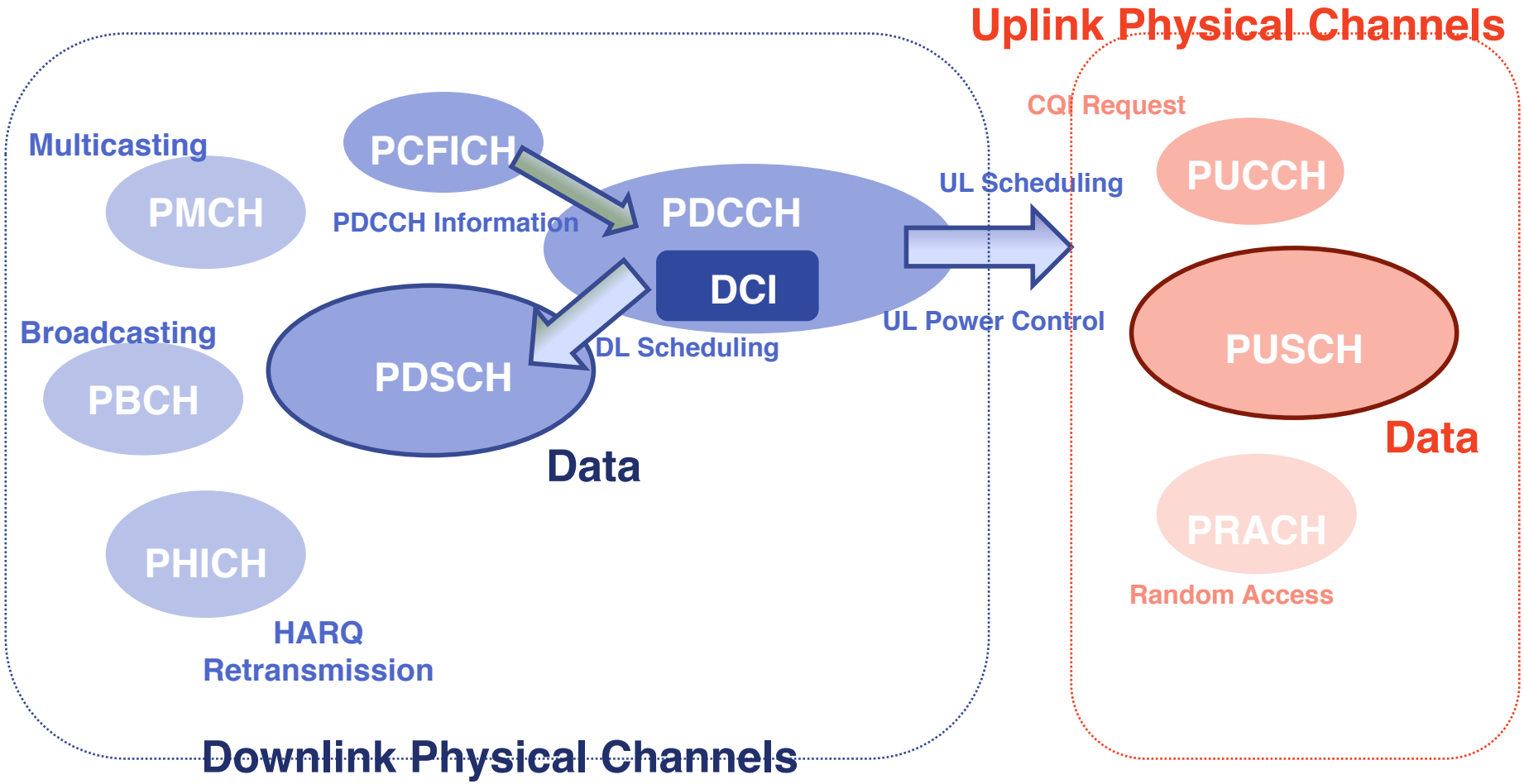


CP Type \ Parameter		N^{*}_{symb}		N^{RB}_{sc}
		N^{DL}_{symb}	N^{UL}_{symb}	
Normal CP	$\Delta f = 15KHz$	**7**	**7**	**12**
Extended CP	$\Delta f = 15KHz$	**6**	**6**	
	$\Delta f = 7.5KHz$	**3**	**-**	**24**

Control Information

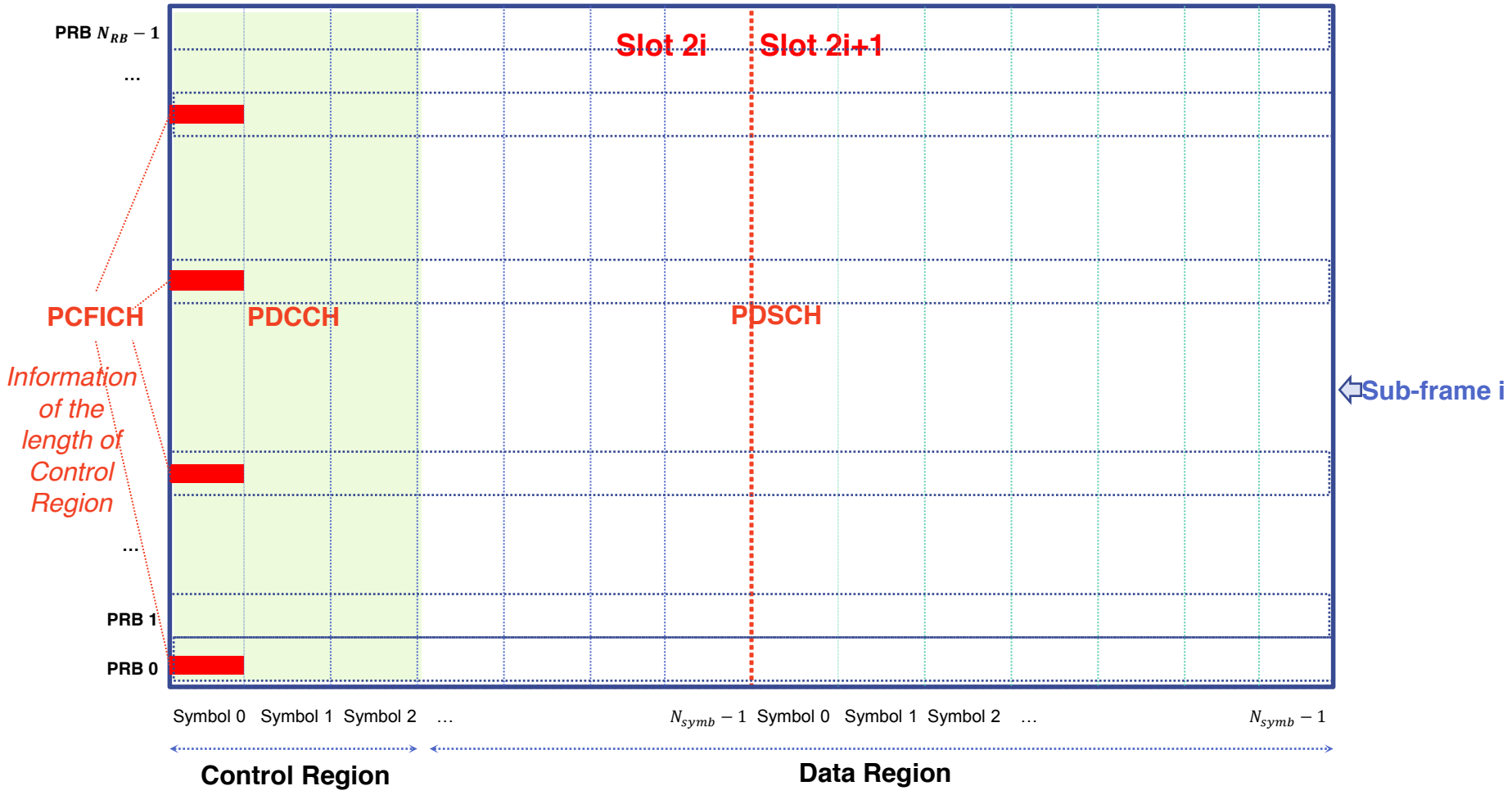
Physical Channels

- **Physical Channels**



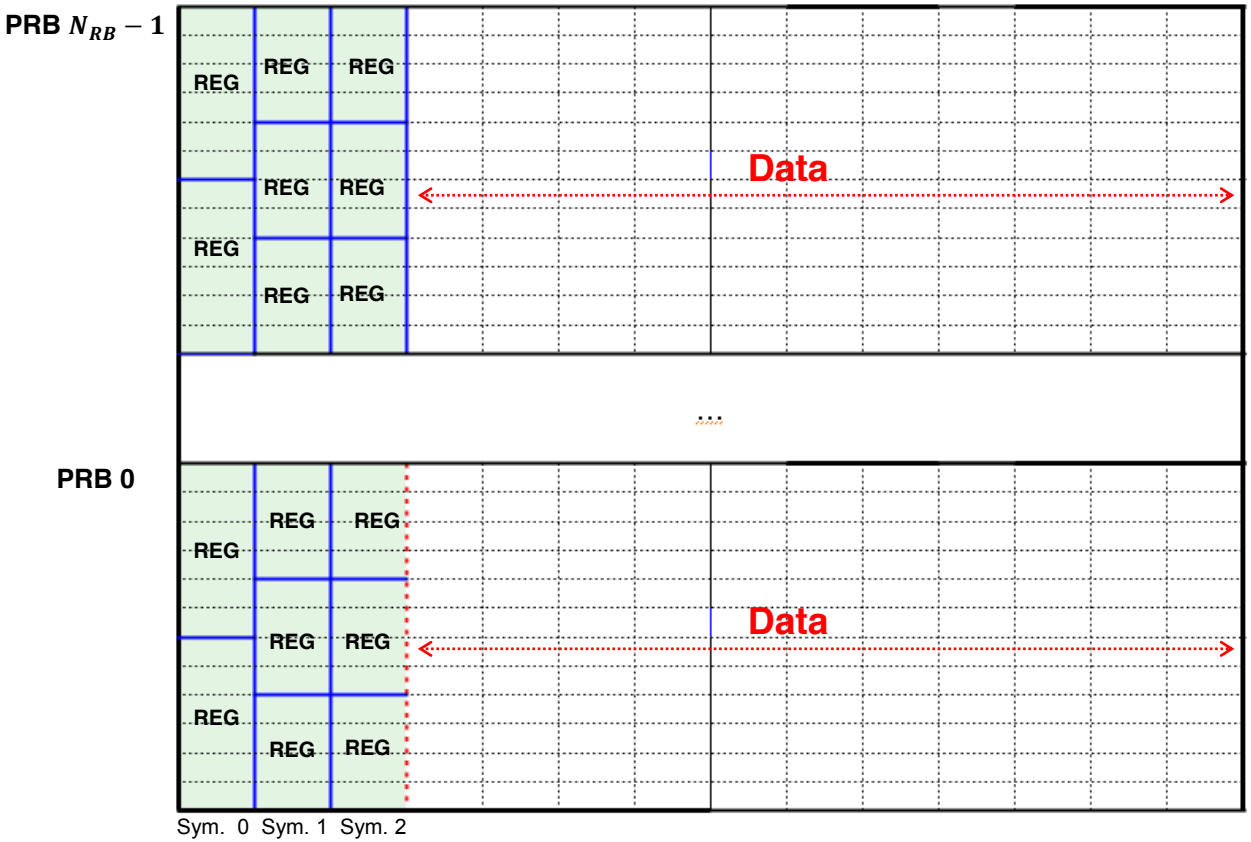
Control & Data Regions

- **Control & Data Region in a DL Sub-frame**



Control Region Mapping

- **Resource Element Group (REG)**
  - ✓ **Used for defining the Control Channel Mapping**



PDCCH

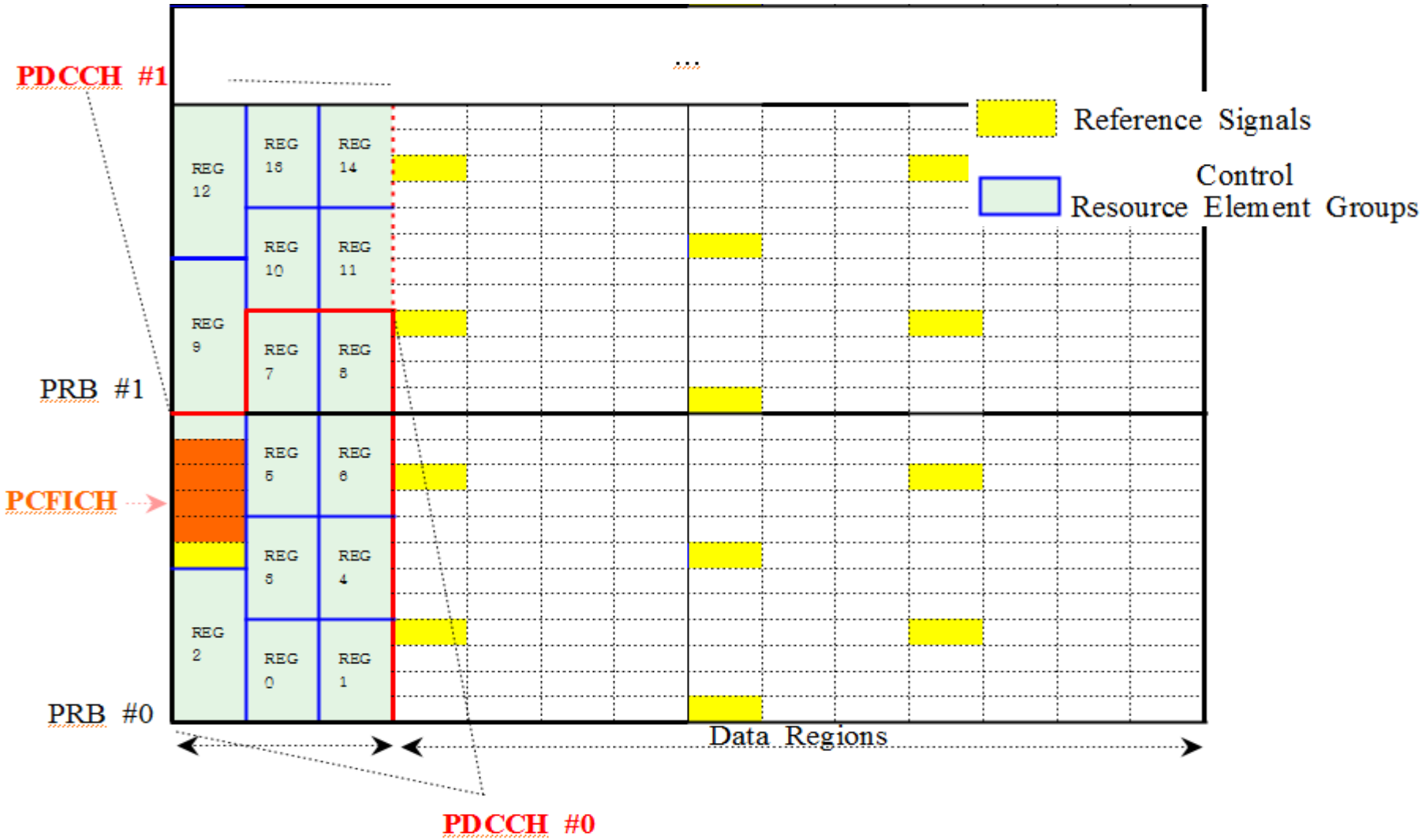
- **Supported PDCCH**

PDCCH Format	Number of CCEs	# Resource Element Group	# PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576

✓ **CCE (Control Channel Element)**

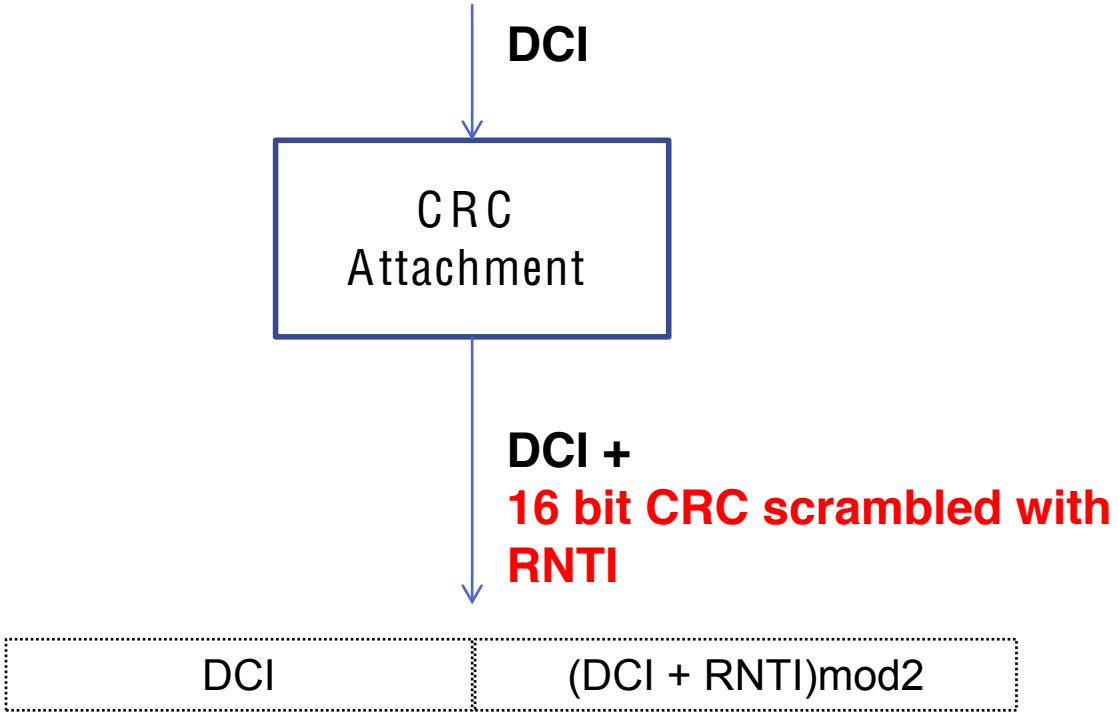
Consist of 9 REG

PDCCH Mapping



User Identification using DCI Scrambling

- **Whose PDCCH (User Identification)?**
  - ✓ **With RNTI (Radio Network Temporary Identifier) : User Identification**



Resource Allocation

Resource Allocations

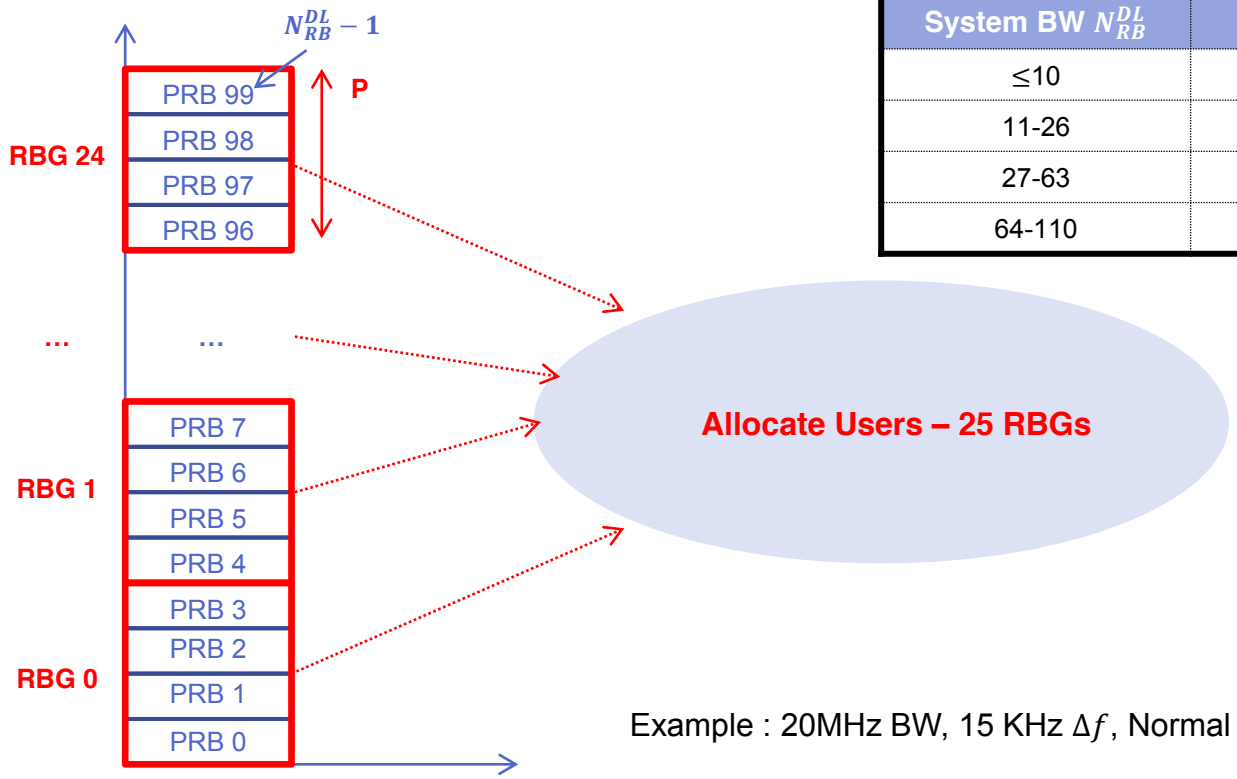
- **Resource Allocation & DCI Formats**

Resource Allocation		Purpose	DCI Format
DL Scheduling	Type 0	Resource Block Group (RBG) based	1
		RBG based (MIMO : Closed Loop)	2
		RBG based (MIMO : Open Loop)	2A
	Type 1	Selected RBG Subset based	1
		Selected RBG Subset based (MIMO : Closed Loop)	2
		Selected RBG Subset based (MIMO Open Loop)	2A
	Type 2	VRB based Compact Scheduling + Random Access	1A
		VRB based Compact Scheduling with MIMO	1B
		VRB based Very Compact Scheduling	1C
		VRB based Compact Scheduling with MIMO & Power Offset	1D
UL Scheduling		VRB based UL Scheduling	0

(Reference : pp. 22-25 3GPP TS 36.213 V8.8.0 (2009-09))

Resource Allocation : DL Type 0

- **Resource Block Groups (RBG) based**



System BW N_{RB}^{DL}	RGB Size (P)
≤10	**1**
11-26	**2**
27-63	**3**
64-110	**4**

Example : 20MHz BW, 15 KHz Δf, Normal CP

(Reference : p. 22 3GPP TS 36.213 V8.8.0 (2009-09))

DL Type 0 (DL Scheduling)

- **DCI Format 1**

Bits	Field
1	Resource Allocation Header: ***Resource Allocation Type 0*** or 1
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	***Resource Assignment***
5	***MCS***
3 or 4	HARQ Process : 3 for FDD, 4 for TDD
1	New Data Indicator
2	Redundancy Version
2	UL Power Control (PUCCH)
2	Downlink Assignment Index : TDD

(Reference : pp. 44-45 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 0 (DL Scheduling with Closed Loop MIMO)

- **DCI Format 2**

Bits	Field
1	Resource allocation header : ***Resource Allocation Type 0*** or type 1
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	***Resource Block Assignment***
2	UL Power Control (PUCCH)
2	Downlink Assignment Index (TDD, Not FDD)
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	Transport block to codeword swap flag
8+8	For transport block 1 & 2 5 bits : ***MCS*** 1 bit : New data indicator 2 bits : Redundancy version
3 or 6	***Closed Loop MIMO*** : 3 (# Ant. ports 2), 6 (# Ant. ports 4)

(Reference : pp. 49-53 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 0 (DL Scheduling with Open Loop MIMO)

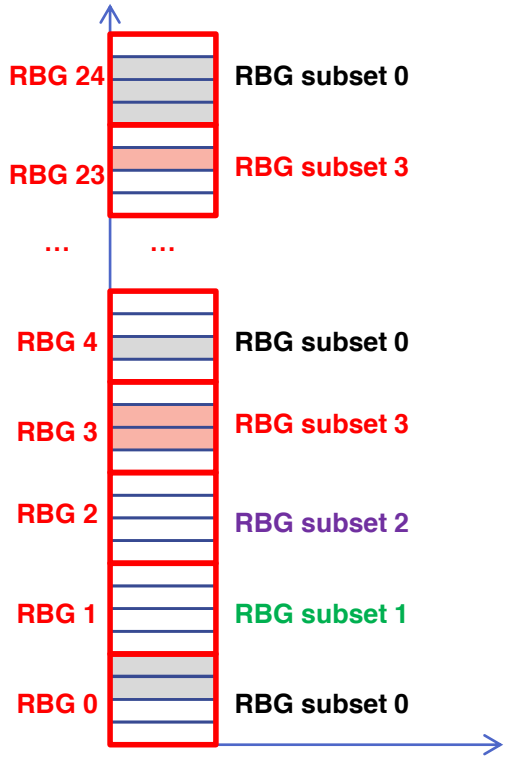
- **DCI Format 2A**

Bits	Field
1	Resource allocation header : ***Resource Allocation Type 0*** or type 1
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	***Resource Block Assignment***
2	UL Power Control (PUCCH)
2	Downlink Assignment Index (TDD, Not FDD)
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	Transport block to codeword swap flag
8+8	For transport block 1 & 2 5 bits : ***MCS*** 1 bit : New data indicator 2 bits : Redundancy version
0 or 2	***Open Loop MIMO*** : 0 (# Ant. ports 2), 2 (# Ant. ports 4)

(Reference : pp. 53-55 3GPP TS 36.212 V8.8.0 (2009-12))

Resource Allocation : DL Type 1

- **Resource Block Groups Subset-based**



Each subsets of PRBs from one of RGB Subset P

Set of PRBs from Subset 0

Set of PRBs from Subset 3

Example : 20MHz BW, 15 KHz Δf, Normal CP

(Reference : p. 23 3GPP TS 36.213 V8.8.0 (2009-09))

DL Type 1 (DL Scheduling)

- **DCI Format 1**

Bits	Field
1	Resource Allocation Header : ***Resource Allocation Type*** 0 or ***1***
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	- $\lceil \log_2(P) \rceil$ **bits** : indicate ***Selected Resource Block Subset*** - **1 bits** : indicate a ***shift of resource allocation span*** - $\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil - \lceil \log_2(P) \rceil - 1$ **bits** : ***Resource Assignment***
5	***MCS***
3 or 4	HARQ Process : 3 for FDD, 4 for TDD
1	New Data Indicator
2	Redundancy Version
2	UL Power Control (PUCCH)
2	Downlink Assignment Index : TDD

(Reference : pp. 44-45 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 1 (DL Scheduling with Closed Loop MIMO)

- **DCI Format 2**

Bits	Field
1	Resource allocation header : ***Resource Allocation Type*** 0 or type ***1***
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	- $\lceil \log_2(P) \rceil$ **bits** : indicate ***Selected Resource Block Subset*** - **1 bits** : indicate a ***shift of resource allocation span*** - $\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil - \lceil \log_2(P) \rceil - 1$ **bits** : ***Resource Assignment***
2	UL Power Control (PUCCH)
2	Downlink Assignment Index (TDD, Not FDD)
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	Transport block to codeword swap flag
16	For transport block 1 & 2 5 bits : ***MCS*** 1 bit : New data indicator 2 bits : Redundancy version
3 or 6	***Closed Loop MIMO*** : 3 (# Ant. ports 2), 6 (# Ant. ports 4)

(Reference : pp. 49-53 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 1 (DL Scheduling with Open Loop MIMO)

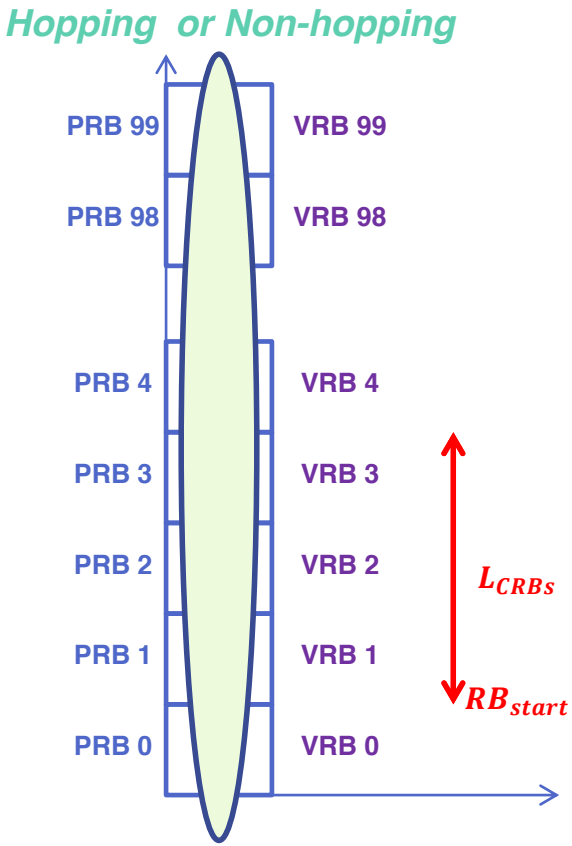
- **DCI Format 2A**

Bits	Field
1	Resource allocation header : ***Resource Allocation Type*** 0 or ***1***
$\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil$	- $\lceil \log_2(P) \rceil$ **bits** : indicate ***Selected Resource Block Subset*** - **1 bits** : indicate a ***shift of resource allocation span*** - $\left\lceil \frac{N_{RB}^{DL}}{P} \right\rceil - \lceil \log_2(P) \rceil - 1$ **bits** : ***Resource Assignment***
2	UL Power Control (PUCCH)
2	Downlink Assignment Index (TDD, Not FDD)
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	Transport block to codeword swap flag
16	For transport block 1 & 2 5 bits : ***MCS*** 1 bit : New data indicator 2 bits : Redundancy version
0 or 2	***Open Loop MIMO*** : 0 (# Ant. ports 2), 2 (# Ant. ports 4)

(Reference : pp. 53-55 3GPP TS 36.212 V8.8.0 (2009-12))

Resource Allocation : DL Type 2

- **Virtual Resource Block (VRB) based**



Allocate Users – Contiguous VRBs

(Reference : p. 24 3GPP TS 36.213 V8.8.0 (2009-09))

DL Type 2 (DL Compact Scheduling + Random Access)

- **DCI Format 1A**

Bits	Field
1	Format Flag : ***Format*** 0 or ***1A***
Case 1	**Random Access Initiated** - 1 bit : 0 (***Localized***) - $\left\lceil \log_2\left(\frac{N_{RB}^{DL}(N_{RB}^{DL}+1)}{2}\right)\right\rceil$ bits : Resource Assignment : all bits 1 Setting - 6 bits : Preamble Index - 4 bits : PRACH Mask Index
Case 2	- 1 bit : ***Localized/Distributed*** VRB assignment flag - $\left\lceil \log_2\left(\frac{N_{RB}^{DL}(N_{RB}^{DL}+1)}{2}\right)\right\rceil$ bits : Resource block assignment - 5 bits : ***MCS*** - 3 or 4 bits : HARQ process number : 3 bits (FDD) , 4 bits (TDD) - 1 bit : New data indicator - 2 bits : Redundancy version - 2 bits : UL Power Control (PUCCH) - 2 bits : Downlink Assignment Index (TDD, not FDD)

(Reference : pp. 45-46 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 2 (DL Compact Scheduling + MIMO)

- **DCI Format 1B**

Bits	Field
1	***Localized/Distributed*** VRB assignment flag
$\left\lceil \log_2\left(\frac{N_{RB}^{DL}\left(N_{RB}^{DL}+1\right)}{2}\right)\right\rceil$	***Resource block assignment***
5	***MCS***
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	New data indicator
2	Redundancy version
2	UL Power Control (PUCCH)
2	Downlink Assignment Index : TDD
2 or 4	***MIMO (TPMI)*** : 2 (# Ant. 2), 4 (# Ant. 4)
1	***MIMO (PMI)***

(Reference : pp. 47-48 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 2 (DL Very Compact Scheduling)

- **DCI Format 1C**

Bits	Field
1	Gap value
≫	***Resource Assignment*** : $\left\lceil \log_2\left(\left\lfloor \frac{N_{VRB,Gap}^{DL}}{N_{RB}^{Step}} \right\rfloor \left(\left\lfloor \frac{N_{VRB,Gap}^{DL}}{N_{RB}^{Step}} \right\rfloor + 1\right)/2\right) \right\rceil$ bits
5	***Transport Block Size***

(Reference : p. 48 3GPP TS 36.212 V8.8.0 (2009-12))

DL Type 2 (DL Compact Scheduling, MIMO, Power Offset)

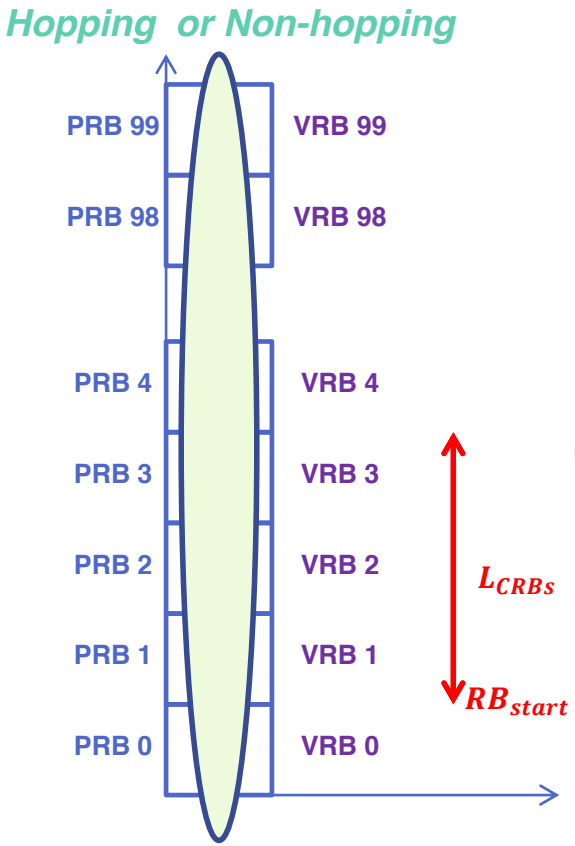
- **DCI Format 1D**

Bits	Field
1	***Localized/Distributed*** VRB assignment flag
$\left\lceil \log_2\left(\frac{N_{RB}^{DL}\left(N_{RB}^{DL}+1\right)}{2}\right)\right\rceil$	***Resource block assignment***
5	***MCS***
3 or 4	HARQ process number : 3 bits (FDD), 4 bits (TDD)
1	New data indicator
2	Redundancy version
2	UL Power Control (PUCCH)
2	Downlink Assignment Index (TDD, not FDD)
2 or 4	***MIMO (TPMI)*** : 2 (# Ant. 2), 4 (# Ant. 4)
1	***MIMO (PMI)***
1	***Downlink power offset***

(Reference : pp. 48-49 3GPP TS 36.212 V8.8.0 (2009-12))

Resource Allocation : UL Type

- **Virtual Resource Block (VRB) based**



Allocate Users – Contiguous VRBs

(Reference : p. 55 3GPP TS 36.213 V8.8.0 (2009-09))

Resource Allocation (UL Scheduling)

- **DCI Format 0**

Bits	Field
1	**Format Flag** : ***Format 0*** or 1A
1	**Hopping Flag** : Non-hopping or Hopping
$\left\lceil \log_2\left(\frac{N_{RB}^{UL}\left(N_{RB}^{UL}+1\right)}{2}\right)\right\rceil$	**- Hopping** $N_{UL,hop}$ bits : **Hopping Location In formation** $\left\lceil \log_2\left(\frac{N_{RB}^{UL}\left(N_{RB}^{UL}+1\right)}{2}\right)\right\rceil - N_{UL,hop}$ **bits** : **Resource Assignment** **- Non Hopping** : $\left\lceil \log_2\left(\frac{N_{RB}^{UL}\left(N_{RB}^{UL}+1\right)}{2}\right)\right\rceil$ **bits** : **Resource Assignment**
5	***MCS***
1	New Data Indicator
2	UL Power Control (PUSCH)
3	Cyclic Shift for DM RS
2	UL Index : TDD
2	Downlink Assignment Index : TDD
1	CQI Request

(Reference : pp. 43-44 3GPP TS 36.212 V8.8.0 (2009-12))

Other DCI Formats

- **Format 3**

  Transmission of TPC commands for PUCCH and PUSCH with 2-bit power adjustments

- **Format 3A**

  Transmission of TPC commands for PUCCH and PUSCH with single bit power adjustments

(Reference : p. 55 3GPP TS 36.212 V8.8.0 (2009-12))

References

References

- TS 36.101 V8.15.0 UE Radio Transmission and Reception
- TS 36.104 V8.12.0 BS Radio Transmission and Reception
- TS 36.201 V8.3.0 LTE PHY General Description
- TS 36.211 V8.9.0 Physical Channels and Modulation
- TS 36.212 V8.8.0 Multiplexing and Channel Coding
- TS 36.213 V8.8.0 Physical Procedures