5G Control Chain Details

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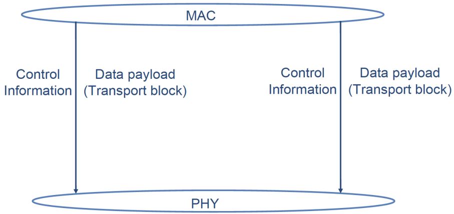
Simulation-Based Design of 5G Wireless Standard (EE698H)

Agenda for today

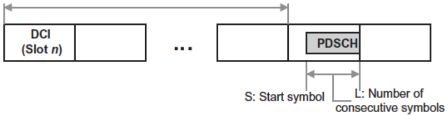
- Briefly discuss 5G control chain
  - Reference – Chap 10.1.4 and 10.1.11 of the 5G NR book by EricD
  - Reference – Chap 3.7.3 and 4.1.3.2.3 of the 5G NR book by SassanA

5G MAC-PHY interface



- MAC layer passes data payload and downlink control information (DCI) to PHY layer
- DCI – MCS index, number of resource blocks, location of resource blocks
- PHY layer first encodes DCI at a particular rate
- PHY layer later maps it using 4-QAM

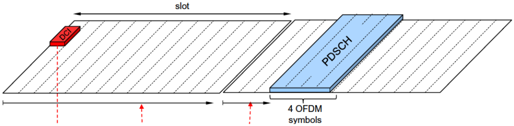
Resource allocation in time domain for downlink (1)



- Slot allocated for PDSCH is determined by $n + K_0$
  - K_0 is the slot offset relative to the slot where DCI was obtained

Resource allocation in time domain for downlink (2)

- Example allocation with start symbol $S = 3$ $L = 4$ consecutive symbols, and slot offset $K_0 = 1$



- Downlink – slot offsets from 0 to 3; uplink – slot offsets from 0 to 7 can be used
- Not all combinations of start and length fit within one slot,
  - for example, starting at OFDM symbol 12 and transmit during five OFDM symbols obviously results in crossing the slot boundary and represents an invalid combination

Time domain resource allocation table for downlink[1]

Row index	*dmrs-TypeA-Position*	PDSCH mapping type	K_0	*S*	*L*
1	2	Type A	0	2	12
	3	Type A	0	3	11
2	2	Type A	0	2	10
	3	Type A	0	3	9
3	2	Type A	0	2	9
	3	Type A	0	3	8
4	2	Type A	0	2	7
	3	Type A	0	3	6
5	2	Type A	0	2	5
	3	Type A	0	3	4
6	2	Type B	0	9	4
	3	Type B	0	10	4
7	2	Type B	0	4	4
	3	Type B	0	6	4
8	2,3	Type B	0	5	7
9	2,3	Type B	0	5	2
10	2,3	Type B	0	9	2
11	2,3	Type B	0	12	2
12	2,3	Type A	0	1	13
13	2,3	Type A	0	1	6
14	2,3	Type A	0	2	4
15	2,3	Type B	0	4	7
16	2,3	Type B	0	8	4

[1] Table 5.1.2.1.1-2 of 38.214. There are 3 more tables.

Resource allocation in time domain for uplink

- BS informs the user in the uplink when to transmit
- DCI is used to schedule users in the uplink also - informally called uplink scheduling grant

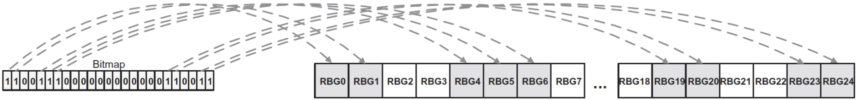
Time domain resource allocation table for uplink[2]

Row index	PUSCH mapping type	K_2	S	L
1	Type A	j	0	14
2	Type A	j	0	12
3	Type A	j	0	10
4	Type B	j	2	10
5	Type B	j	4	10
6	Type B	j	4	8
7	Type B	j	4	6
8	Type A	j+1	0	14
9	Type A	j+1	0	12
10	Type A	j+1	0	10
11	Type A	j+2	0	14
12	Type A	j+2	0	12
13	Type A	j+2	0	10
14	Type B	j	8	6
15	Type A	j+3	0	14
16	Type A	j+3	0	10

[2] Table 6.1.2.1.1-2 of 38.214

Downlink resource allocation in freq. domain (1)

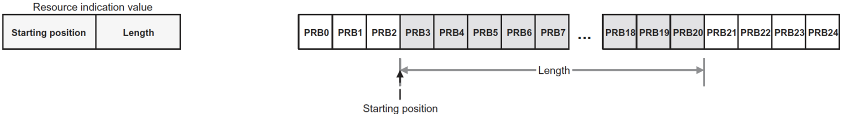
- A UE determines the frequency-domain resources on which it transmits or receives data by examining the resource-block allocation
- Base station can signal the allocated resources to a UE using resource allocation type 0 or type 1
- Type 0 is a bitmap-based allocation scheme



  - Indicates set of resource block groups that UE is supposed to receive in the downlink
  - Size of the bitmap is equal to the number of resource blocks group

Downlink resource allocation in freq. domain (2)

- Type 1 combines starting position and length of resource allocation values into a single value



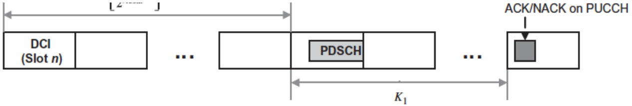
  - Referred to as resource indication value

Contents of DCI (1)

- DCI is used for both downlink and uplink scheduling
- Multiple DCI formats - e.g., "DCI Format 1_0", which is used for downlink scheduling
- Length of this format is around 35 bits
  - Modulation and coding scheme (5 bits)
  - New data indicator (1 bit)
  - Redundancy version (2 bits)
  - Time-domain resource assignment (4 bits)
  - Frequency-domain resource assignment
  - VRB-to-PRB mapping (1 bit) - continuous / interleaved
  - Identifier for DCI format (1 bit) - downlink assignment / uplink grant

Contents of DCI (2)

- DCI is used for both downlink and uplink scheduling
- Multiple DCI formats - e.g., “DCI Format 1_0”, which is used for downlink scheduling
- Length of this format is around 35 bits
  - PDSCH-to-HARQ feedback timing indicator (3 bits)
    - indicates HARQ ACK/ NAK timing relative to the PDSCH transmission



  - Few other fields

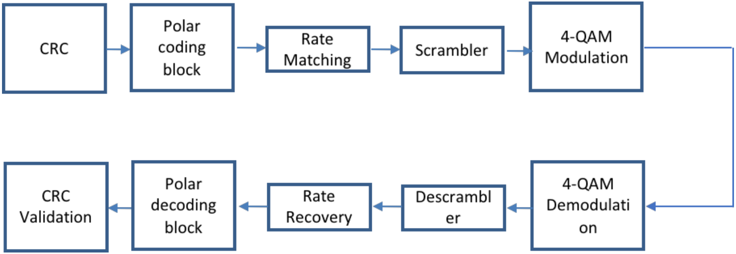
Comparison of two different DCI types for downlink

Field		Format 1–0	Format 1–1
Format identifier		•	•
Resource information	CFI		•
	BWP indicator		•
	Frequency domain allocation	•	•
	Time-domain allocation	•	•
	VRB-to-PRB mapping	•	•
	PRB bundling size indicator		•
	Reserved resources		•
	Zero-power CSI-RS trigger		•
Transport-block related	MCS	•	•
	NDI	•	•
	RV	•	•
	MCS, 2nd TB		•
	NDI, 2nd TB		•
	RV, 2nd TB		•
Hybrid-ARQ related	Process number	•	•
	DAI	•	•
	PDSCH-to-HARQ feedback timing	•	•
	CBGTI		•
	CBGFI		•
Multi-antenna related	Antenna ports		•
	TCI		•
	SRS request		•
	DM-RS sequence initialization		•
PUCCH-related information	PUCCH power control	•	•
	PUCCH resource indicator		•

Comparison of two different DCI types for uplink

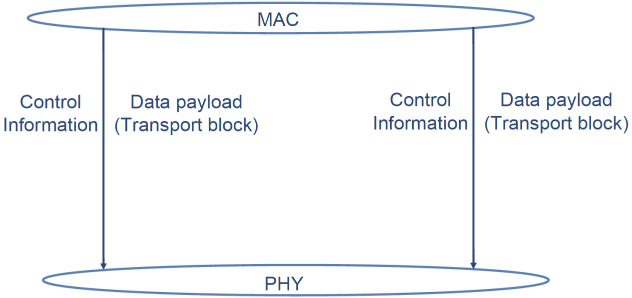
Field		Format 0–0	Format 0–1
Identifier		•	•
Resource information	CFI		•
	UL/SUL	•	•
	BWP indicator		•
	Frequency domain allocation	•	•
	Time-domain allocation	•	•
	Frequency hopping	•	•
Transport-block-related	MCS	•	•
	NDI	•	•
	RV	•	•
Hybrid-ARQ-related	Process number	•	•
	DAI		•
	CBGTI		•
Multi-antenna-related	DM-RS sequence initialization		•
	Antenna ports		•
	SRI		•
	Precoding information		•
	PTRS–DMRS association		•
	SRS request		•
	CSI request		•
Power control	PUSCH power control	•	•
	Beta offset		•

PHY layer processing of DCI – Overview



- Polar decoding block is the most complicated block
- Low BLER for short block lengths
- Low power and hardware consumption for PDCCH decoding, which a user performs

5G PHY processing summary



- Understood in detail PHY layer processing of PDSCH
- Had a overview of PDCCH PHY layer processing