



Support of cross-carrier scheduling with different numerologies in Rel-15

Huawei, HiSilicon

Background

- There was discussion in RAN1#94 that cross-carrier scheduling with different numerologies are not completed in Rel-15
- This paper analyzes the status on the support of cross-carrier scheduling with different numerologies in Rel-15

Analysis for cross-carrier scheduling with different numerologies

Contents		Specification	Completeness
DL control	Carrier indicator in DCI	TS38.212, subclauses 7.3.1.1.2/7.3.1.2.2	Completed
	Search space	TS38.213, subclause 10.1	Completed
	BD/CCE limit	Not defined for X-scheduling with different numerologies	Incomplete
	DCI size budget	TS38.212, subclause 7.3.1.1.1/7.3.1.2.1 TS38.213, subclause x.x	Completed
UL control	HARQ-ACK	TS38.213, subclauses 9.1.2/9.1.3	Completed
Scheduling	Time granularity (K0, K2)	TS38.214, subclauses 5.1.2.1/6.1.2.1	Completed
	Time granularity (K1)	TS38.213, subclause 9.2.3	Completed
	Causality constraint	Not defined for X-scheduling with different numerologies	Incomplete
HARQ processing time	UE processing capability #1	TS38.214, subclause 5.3/6.4	Completed
	UE processing capability #2	Not defined for X-scheduling with different numerologies	Incomplete

BD/CCE limit

- Status: some agreement made; further agreements needed

Relationship between 4, y and T	Self-scheduling		Cross-carrier scheduling	
	Same numerology	Mixed numerologies	Same numerology	Mixed numerologies
T=4 or 4<T<y	Case 1 Agreement		Case 4 Agreement	Case 6 No agreement
T>4 and T>y	Case 2 Agreement	Case 3 Agreement	Case 5 Agreement	Case 7 No agreement
Notes	T: The number of DL-CCs aggregated (1, .., 16); y: BD capability (4, ..., 16)			

- Impact analysis:
 - This issue requires additional discussion on the Case 6 and Case 7 and reach agreements
 - Several alternatives already proposed and discussed in RAN1#94, see offline summary in R1-1809855 section 2.8 (extracted below)

Offline proposal:

- For cross-carrier scheduling with mixed numerologies, and the number of DL-CCs is up to 4 or with up to T DL-CCs where the UE reports BD capability of $y \geq T$,..
 - If there are N scheduling cells where the numerology of the nth scheduling cell is $\mu(n)$ with $n=1 \sim N$ and $\mu(n)=0 \sim 3$, and the nth scheduling cell has $X(n)$ schedulable DL cells with numerology i with $i=0 \sim 3$, the limit of BDs/CCEs of the nth scheduling CC per slot is given by $\sum_{i=0}^3 X_i(n) \times (M_i \text{ or } N_i) \times 2^{i-\mu(n)}$, where M_i and N_i denote the limit of BDs and CCEs per slot for non-CA case for numerology i, respectively..
 - The total limit of BDs/CCEs can be split across schedulable CCs for the same scheduling CC, subject to the non-CA limit on each CC..

Offline proposal:

- For cross-carrier scheduling with mixed numerologies, and the number of DL-CCs is more than 4 and with up to T DL-CCs where the UE reports BD capability of $y < T$,..
 - If there are N scheduling cells where the numerology of the nth scheduling cell is $\mu(n)$ with $n=1 \sim N$ and $\mu(n)=0 \sim 3$, and the nth scheduling cell has $X(n)$ schedulable DL cells with numerology i with $i=0 \sim 3$, the limit of BDs/CCEs of the nth scheduling CC per slot is given by $\left[\sum_{i=0}^3 X_i(n) \times (M_i \text{ or } N_i) \times 2^{i-\mu(n)} \times \frac{X_i}{X_0+X_1+X_2+X_3} \right]$, where M_i and N_i denote the limit of BDs and CCEs per slot for non-CA case for numerology i, respectively..
 - The total limit of BDs/CCEs can be split across schedulable CCs for the same scheduling CC, subject to the non-CA limit on each CC..

- Proposal: handle this issue as Rel-15 correction**
HUAWEI TECHNOLOGIES CO., LTD., Proprietary

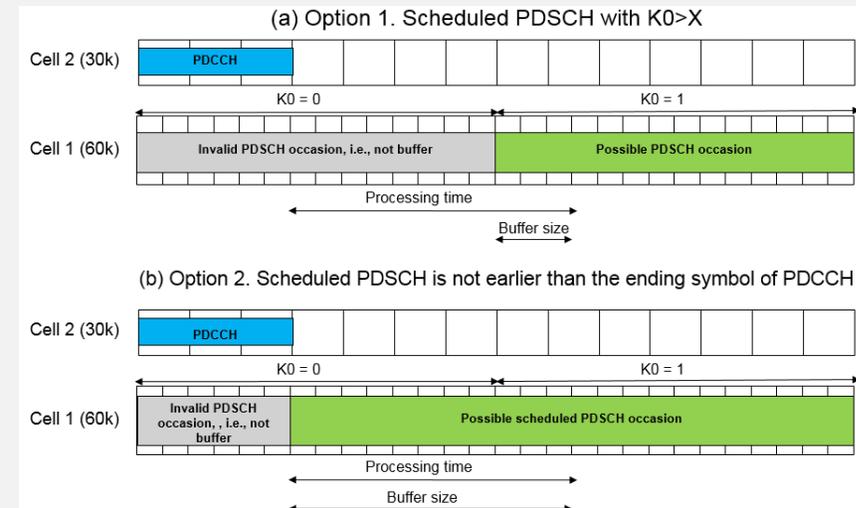
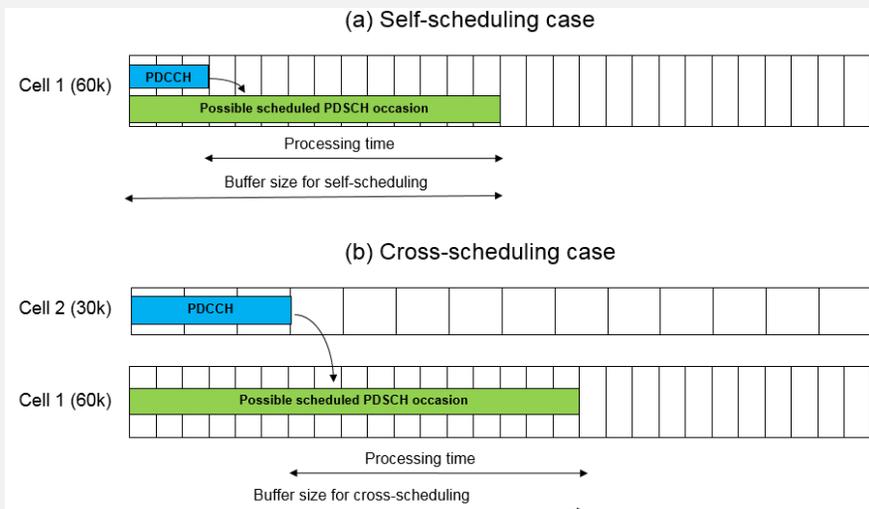
Causality Constraint

- Status: some agreement made; further agreements needed

Agreements(RAN1#93):

- Cross-carrier scheduling should at least satisfy the causality constraints between scheduling PDCCH and PDSCH as for self-scheduling, also taking into carrier timing difference
 - Note: in the case of mixed numerology, limitations on the number of symbols to buffer need to be taken into account
 - For cross-carrier scheduling across different numerology
 - FFS: how to specify additional constraints related to K_0 to address the number of symbols which may need to be buffered
- Impact analysis:
 - This issue only applies for PDCCH on a carrier with smaller SCS scheduling PDSCH on a carrier with larger SCS
 - Several simple solution already proposed by companies

Proposal: handle this issue as Rel-15 correction



UE processing capability #2

- Status:
 - Values of UE processing capability #2 were agreed assuming same carrier scheduling;
 - Support of cross-carrier scheduling with same or different numerologies has not been agreed for UE processing capability #2

Agreements(RAN1#94) on UE processing capability #2 for UE feature list (R1-1809998):

#	Feature group	Components
1 [5-5a]?	UE PDSCH processing capability #2	<p>UE can report values 'X' and 'Fallback', and supports the following operation, only when all carriers are self-scheduled and all Capability #2 carriers in a band are of the same numerology</p> <ul style="list-style-type: none"> • UE supports Capability #2 processing time on all configured carriers if # configured carriers in a band <= X, otherwise <ul style="list-style-type: none"> ○ If Fallback = 'SC', UE supports Capability #2 processing time on lowest cell index among the configured carriers in the band where the value is reported ○ If Fallback = 'Cap1-only', UE supports only Capability #1, in the band where the value is reported <p>2) No scheduling limitation 3) N1 based on Table 5.3-2 of TS 38.214 for given SCS from {15, 30, 60} kHz</p>
3 [5-5c]?	UE PUSCH processing capability #2	<p>UE can report values 'X' and 'Fallback', and supports the following operation, only when all carriers are self-scheduled and all Capability #2 carriers in a band are of the same numerology</p> <ul style="list-style-type: none"> • UE supports Capability #2 processing time on all configured carriers if # configured carriers in a band <= X, otherwise <ul style="list-style-type: none"> ○ If Fallback = 'SC', UE supports Capability #2 processing time on lowest cell index among the configured carriers in the band where the value is reported ○ If Fallback = 'Cap1-only', UE supports only Capability #1, in the band where the value is reported <p>2) N2 based on Table 6.4-2 of TS 38.214 for given SCS from {15, 30, 60} kHz</p>

- Impact analysis:
 - Support of cross-carrier scheduling with capability #2 may require additional discussion on the achievable values for UE processing capability #2
- **Proposal: It is left to WGs to decide whether to support cross-carrier scheduling (with same or different numerology) for UE processing capability #2 in Rel-15**

Summary of proposals

- Cross-carrier scheduling with different numerologies is kept in Rel-15
- Address the BD/CCE limit for cross-carrier scheduling with different numerologies as Rel-15 correction
- Address the causality issue as Rel-15 correction
- It is left to WGs to decide whether to support cross-carrier scheduling (with same or different numerology) for UE processing capability #2 in Rel-15

Thank you !

