**3GPP TSG RAN WG1#104-e R1-2xxxxxx**

**e-Meeting, January 25th – February 5th, 2021**

**Agenda Item: 8.2.2**

**Source: Moderator (none)**

**Title: [Draft] PDCCH Monitoring Alternatives**

**Document for: Discussion, Decision**

# Discussion on PDCCH Monitoring Alternatives

## Current version (as of Tuesday 01:05 UTC) – with markup

* Alt 1: A fixed pattern of X slots.
  + The different X slot groups are consecutive and do not overlap
  + PDCCH could be configured in ~~the first~~ Y consecutive slots within each X slot group
  + BD/CCE budget is counted within the Y slots of each X slot group, ~~and different X slot groups do not overlap~~
  + Alt 1-1: Y<X~~, BD/CCE budget is counted within the first Y slots of each X slot group, and the X slot groups do not overlap for different countings.~~
    - FFS: The Y slots are the first Y slots within the X slot group or not
  + Alt 1-2: Y=X~~, BD/CCE budget is counted for each X=Y slot group, and the X slot groups do not overlap for different countings.~~
  + Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
  + Y<=X
  + PDCCH could be configured such that the developed span pattern by SS configuration satisfy (X,Y) requirement, i.e. the start of any two span of at most Y symbols/slots is separated by at least X symbols/slots
  + BD/CCE budget is counted for each span of at most Y symbols/slots
  + FFS: Values of X and Y and units in which they are defined
  + ~~FFS: Whether number of slots within which the number of monitoring occasions is counted is needed and if needed, the value of the number of slots~~
* Alt 3: A sliding window of X=Y slots for defining multi-slot PDCCH monitoring capability.
  + The slot groups are sliding in unit of [1] slot
  + PDCCH could be configured in any slot
  + BD/CCE budget is counted within any slot group ~~consecutive X=Y slots~~
  + ~~FFS: Increments in which sliding occurs~~

## Clean version (as of Tuesday 1:05 UTC)

* Alt 1: A fixed pattern of X slots.
  + The different X slot groups are consecutive and do not overlap
  + PDCCH could be configured in Y consecutive slots within each X slot group
  + BD/CCE budget is counted within the Y slots of each X slot group
  + Alt 1-1: Y<X
    - FFS: The Y slots are the first Y slots within the X slot group or not
  + Alt 1-2: Y=X
  + Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
  + Y<=X
  + PDCCH could be configured such that the developed span pattern by SS configuration satisfy (X,Y) requirement, i.e. the start of any two span of at most Y symbols/slots is separated by at least X symbols/slots
  + BD/CCE budget is counted for each span of at most Y symbols/slots
  + FFS: Values of X and Y and units in which they are defined
* Alt 3: A sliding window of X=Y slots for defining multi-slot PDCCH monitoring capability.
  + The slot groups are sliding in unit of [1] slot
  + PDCCH could be configured in any slot
  + BD/CCE budget is counted within any slot group

## Update from Ericsson

* Alt 1: A fixed pattern of contiguous slot groups.
  + Each slot group consists of X slots
  + PDCCH monitoring can be configured in Y consecutive slots within each X slot group
  + BD/CCEs are counted toward the budget within the Y slots of each X slot group
    - Note: BD/CCEs are not counted across slot group boundaries
  + Alt 1-1: Y<X
    - FFS: Whether or not the Y slots are the first Y slots within each X slot group
  + Alt 1-2: Y=X
    - Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
  + Y<=X
  + PDCCH monitoring can be configured such that the span pattern by search space configuration satisfies the (X,Y) requirement, i.e. X is the minimum time separation between the the start of two consecutive spans, including across slot groups
  + BD/CCEs are counted toward the budget for each span of at most Y symbols/slots
  + FFS: Values of X and Y and units in which they are defined
* Alt 3: Same as Alt-1-2 (Y=X), except
  + BD/CCEs are counted toward the budget within an X slot sliding window that can cross a slot-group boundary
  + The window slides in unit of [1] slot
  + PDCCH monitoring can be configured in any slot within a slot group

Comments:

* For Alt-1, I modified the first two lines to make it more clear that the pattern is not X slots. Rather, the pattern consists of contiguous slot groups where each slot group consists of X slots
* For Alt-2, aligned the wording to be close to what is in he current 38.213 Section 10, However, what was missing from the Alt-2 description is the implicit sliding window. So I added "including across slot groups" analogous to current 38.213

A UE can indicate a capability to monitor PDCCH according to one or more of the combinations = (2, 2), (4, 3), and (7, 3) per SCS configuration of and . A span is a number of consecutive symbols in a slot where the UE is configured to monitor PDCCH. Each PDCCH monitoring occasion is within one span. If a UE monitors PDCCH on a cell according to combination , the UE supports PDCCH monitoring occasions in any symbol of a slot with minimum time separation of symbols between the first symbol of two consecutive spans, including across slots. A span starts at a first symbol where a PDCCH monitoring occasion starts and ends at a last symbol where a PDCCH monitoring occasion ends, where the number of symbols of the span is up to .

* Question to all: I'm not convinced that the following is accurate. What happens if there are two spans within a slot group that satisfy the (X,Y) requirement? Is it necessary to introduce a third variable N = number of slots in slot group?

"BD/CCEs are counted toward the budget for each span of at most Y symbols/slots"

## Update from vivo

* Alt 1: A fixed pattern of X slots.
  + The different X slot groups are consecutive and do not overlap
  + PDCCH could be configured in Y consecutive slots within each X slot group
  + BD/CCE budget is counted within the Y slots of each X slot group
  + Alt 1-1: Y<X
    - FFS: The Y slots are the first Y slots within the X slot group or not
  + Alt 1-2: Y=X
  + Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
  + Y<=X
  + PDCCH could be configured such that the developed span pattern by SS configuration satisfy (X,Y) requirement, i.e. the start of any two consecutive span of at most Y symbols/slots is separated by at least X symbols/slots
  + BD/CCE budget is counted for each span of at most Y symbols/slots
  + FFS: Values of X and Y and units in which they are defined
  + FFS: Whether number of slots within which ~~the number of monitoring occasions is counted~~ the span pattern is repeated is needed and if needed, the value of the number of slots
* Alt 3: A sliding window of X=Y slots for defining multi-slot PDCCH monitoring capability.
  + The slot groups are sliding in unit of [1] slot
  + PDCCH could be configured in any slot
  + BD/CCE budget is counted within any slot group

Comments:

* For Alt-1, it seems that we already have common understanding on this. The wording refinement from Ericsson is also fine with us.
* For Alt-2, I think the original FFS is still needed but the wording should be adjusted to make it clearer. In single-slot monitoring capability defined in NR Rel-15/16, the multi-symbol span pattern is repeated every slot and there may be multiple spans within one slot. Similarly, to define multi-slot monitoring capability, the multi-symbol/slot span pattern should be repeated in multiple (e.g. M, M>X>=Y) slots. One example could be that the span pattern is repeated in every subframe. Then N is actually the number of slots within which the span pattern is repeated, which is updated as above.
* For Alt-3, it is similar to Alt 1-2 except the BD/CCE counting.

In all the above alternatives, the above mentioned Y slots doesn’t mean all symbols in the slot are monitored. Which symbol needs to be monitored will be further discussed.

## Update from Huawei

It might be more convenient for discussion to provide updates on top of the already made agreement, but these change marks have been lost in the updates above. Here is an update considering revisions provided by Ericsson and vivo.

* My understanding of vivo’s description of Alt2 is that it would be another alternative where a “span pattern is repeated” (e.g. Alt4 requiring 3 parameters instead of 2).
* Ericsson’s “including across slot groups” for Alt2 is ambiguous because “slot groups” are undefined in Alt2. I tentatively replaced by “irrespective of the starting symbol of a span”

**Proposed revised agreement**

Choose one of the following alternatives for defining the multi-slot PDCCH monitoring capability

* Alt 1: A fixed pattern of X-slot groups.
  + Each slot group consists of X slots
  + The different X slot groups are consecutive and do not overlap
  + PDCCH monitoring can be configured in Y consecutive slots within each X-slot group
  + BD/CCEs are counted toward the budget within the Y slots of each X slot group
    - Note: BD/CCEs are not counted across slot group boundaries
  + Alt 1-1: Y<X
    - FFS: Whether or not the Y slots are the first Y slots within the X-slot group
  + Alt 1-2: Y=X
    - Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
  + Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
  + Y<=X
  + PDCCH monitoring can be configured such that the span pattern by search space configuration satisfies the (X,Y) requirement, i.e. X is the minimum time separation between the start of two consecutive spans, irrespective of the starting symbol of a span
  + BD/CCEs are counted toward the budget for each span of at most Y [symbols or slots]
  + FFS: Values of X and Y and units in which they are defined
* Alt 3: A sliding window of X=Y slots
  + BD/CCEs are counted toward the budget within an X-slot sliding window that can cross a slot-group boundary
  + The window slides in unit of [1] slot
  + PDCCH monitoring can be configured in any slot within a slot group of X slots
  + Note: X and Y are used to facilitate discussion. If Alt 1-3 is agreed, Y is not needed.

## Update from LG

We are generally fine with Huawei’s version. From this, some modifications have been made for a clearer understanding.

* Alt 1: Use a fixed pattern of X-slot groups as the baseline to define the new capability
  + Each slot group consists of X slots
  + The different X-slot groups are consecutive and do not overlap
  + PDCCH monitoring can be configured in Y consecutive slots within each X-slot group
  + BD/CCEs are counted toward the budget within the Y slots of each X-slot group
    - Note: BD/CCEs are not counted across slot group boundaries
  + Alt 1-1: Y<X
    - FFS: Whether or not the Y slots are the first Y slots within the X-slot group
  + Alt 1-2: Y=X
    - Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) span as the baseline to define the new capability
  + Y<=X
  + PDCCH monitoring can be configured such that the span pattern by search space configuration satisfies the (X,Y) requirement, i.e. X is the minimum time separation between the start of two consecutive spans, irrespective of the starting symbol of a span
  + BD/CCEs are counted toward the budget for each span of at most Y [symbols or slots]
  + FFS: Values of X and Y and units in which they are defined
* Alt 3: Use a sliding window of X=Y slots as the baseline to define the new capability
  + BD/CCEs are counted toward the budget within an X-slot sliding window that can cross a slot-group boundary
  + The window slides in unit of [1] slot
  + PDCCH monitoring can be configured in any slot within a slot group of X slots
  + Note: X and Y are used to facilitate discussion. If Alt 3 is agreed, Y is not needed.

## Update from ZTE

The following update is based on LG’s version.

* For Alt 1, we understand that “Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.” is a common description/explanation. Therefore, it may be more suitable to be placed in a separate bullet.
* For Alt2, it is not clear for the sentence of “irrespective of the starting symbol of a span”. because so far some contents have not been determined/agreed/reached a consensus, for example, is the start of a span based on slot boundary or symbol boundary? And how to determine the starting position of a span?. therefore, we think such description on “irrespective of the starting **symbol** of a span” is not suitable and accurate to put it here.
* Besides, in our understanding, “**across slot**” mentioned in Clause 10 of the current TS 38.213, its means even if two consecutive spans are located in two different slots (across slot), the time gap of the start of these two spans should also satisfy the minimum time value X.

**Proposed revised agreement**

Choose one of the following alternatives for defining the multi-slot PDCCH monitoring capability

* Alt 1: Use a fixed pattern of X-slot groups as the baseline to define the new capability
  + Each slot group consists of X slots
  + The different X-slot groups are consecutive and do not overlap
  + PDCCH monitoring can be configured in Y consecutive slots within each X-slot group
  + BD/CCEs are counted toward the budget within the Y slots of each X-slot group
    - Note: BD/CCEs are not counted across slot group boundaries
  + Alt 1-1: Y<X
    - FFS: Whether or not the Y slots are the first Y slots within the X-slot group
  + Alt 1-2: Y=X
  + Note: Y is used to facilitate discussion. If Alt 1-2 is agreed, Y is not needed.
* Alt 2: Use (X,Y) span as the baseline to define the new capability
  + Y<=X
  + PDCCH monitoring can be configured such that the span pattern by search space configuration satisfies the (X,Y) requirement, i.e. X is the minimum time separation between the start of two consecutive spans
  + BD/CCEs are counted toward the budget for each span of at most Y [symbols or slots]
  + FFS: Values of X and Y and units in which they are defined
* Alt 3: Use a sliding window of X=Y slots as the baseline to define the new capability
  + BD/CCEs are counted toward the budget within an X-slot sliding window that can cross a slot-group boundary
  + The window slides in unit of [1] slot
  + PDCCH monitoring can be configured in any slot within a slot group of X slots
  + Note: X and Y are used to facilitate discussion. If Alt 3 is agreed, Y is not needed.

## Moderator suggestion for further discussion

In the following, I try to show my understanding based on the previous revisions in this document, by change marks against the defined alternatives acccording to the agreement.

At the same time, some of the concerns regarding back-to-back monitoring configurations that are being addressed by Alt 3 could be avoided by proper values of X/Y in Alt 1 and Alt 2 in my view, if we agree e.g. that PDCCH monitoring is limited to within first N slots of a monitoring span. That could be part of the further discussion to choose down between the alternatives.

We also need to keep in mind that the monitoring occasion configuration is not necessarily fully aligned with X,Y values for the capability, this could be the subject of later discussion. Most of the revised suggestions anyway state that the monitoring "can"/"could" be configured in a certain manner, which seems not a tight requirement that these would be the only supported configurations. Therefore I do not include such configuration aspects right now in my suggestion (even though it is acknowledged that such descriptions have a benefit to understand how the capability and configuration can share a common framework).

Proposed modification of agreement:

Choose one of the following alternatives for defining the multi-slot PDCCH monitoring capability

* Alt 1: Use a fixed pattern in a slot group as the baseline to define the new capability.
  + Each slot group consists of X slots
  + Slot groups are consecutive and non-overlapping
  + The capability indicates how much BD/CCE budget is available within Y consecutive [symbols or slots] in each slot group
    - FFS: Supported values/constraints of X and Y, e.g. Y<=X, Y=X
    - FFS: Restrictions on location of the Y [symbols or slots] within a slot group, e.g. the Y [symbols or slots] always start at the first symbol of the first slot within a slot group
* Alt 2: Use an (X,Y) span as the baseline to define the new capability
  + X is the minimum time separation between the first symbol of two consecutive spans
  + The capability indicates how much BD/CCE budget is available within Y consecutive [symbols or slots] in a span
  + Y <= X
  + FFS: Exact values of X and Y and units in which they are defined, including cases where a span is longer than one slot or crosses a slot boundary.
* Alt 3: Use a sliding window of X slots as the baseline to define the new capability.
  + The capability indicates how much BD/CCE budget is available within the sliding window
  + The sliding unit of the sliding window is [1] slot.
* Specific numbers for X, Y may depend on UE capability and gNB configuration
  + Examples:
    - X = [4] slots for 480 kHz SCS and X = [8] slots for 960 kHz SCS

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| --- | --- |
| **Company** | **Comment** |
| Intel | For Alt 1, suggest to change ‘Y [symbols or slots]’ to ‘Y slots’, since there is no proposal that Y is 1/2/3 symbols of CORESET duration. |
| Samsung | For Alt 2, suggest the following changes to be aligned with definition of Y in 38.213:   * + The capability indicates how much BD/CCE budget is available within a span of at most Y consecutive [symbols or slots] ~~in a span~~ |
| MediaTek | Thanks for the good discussion. We have some comments on Alt1 as below. 1. We suggest to move the two FFS points in Alt1 one level up to align with the bullet structure in Alt2.  2. For the second FFS, FFS: Restrictions on location of the Y [symbols or slots] within a slot group, e.g. the Y [symbols or slots] always start at the first symbol of the first slot within a slot group  The wording is a little bit confusing for the case that the unit of Y is slot. In our understanding, if the unit of Y was slot, we still need to specify the monitoring occasion configuration within each slot of the Y slots. Therefore, we suggest the following modification:  FFS: Restrictions on location of the Y [symbols or slots] within a slot group, e.g. the Y [symbols or slots] always start at the [first symbol of the first slot or first slot] within a slot group.  FFS: Restrictions on monitoring occasion location within each slot of the Y slots if the unit of Y is defined as slot. |
| Apple | For Alt-1, we would like to keep it as [Symbols/slots] as we have not yet decided what the units will be.  From the email discussion, in Alt-2 there seemed to be consensus to keep the statement   * “FFS: Whether number of slots within which ~~the number of monitoring occasions is counted~~ the span pattern is repeated is needed and if needed, the value of the number of slots” |
| Huawei, HiSilicon | In response to Apple’s comment, our preference was not to keep the text “the span pattern is repeated”. It might be naturally repeated based on the search space configuration, e.g. Y is 3 symbols in the first slot every X slots, without needing to define yet another parameter for it. But if we have an FFS, does this mean it might be precluded unless we resolve the FFS?  We support the suggestions from Intel and Samsung. |
| vivo | We agree with Apple to keep the following statement:  “FFS: Whether number of slots within which ~~the number of monitoring occasions is counted~~ the span pattern is repeated is needed and if needed, the value of the number of slots”  In response to Huawei’s comment, I don’t think the span pattern is naturally repeated since the span pattern is not determined by one search space but all the configured search spaces. Besides, X is the minimum gap between any two spans which means the gap between two spans is not fixed in Alt. 2.  Here I copied the spec on how to determine span pattern in NR Rel-15 below:  In order to determine a suitable span pattern, first a bitmap b(l), 0<=l<=13 is generated, where b(l)=1 if symbol l of any slot is part of a monitoring occasion, b(l)=0 otherwise. The first span in the span pattern begins at the smallest l for which b(l)=1. The next span in the span pattern begins at the smallest l not included in the previous span(s) for which b(l)=1. The span duration is max{maximum value of all CORESET durations, minimum value of Y in the UE reported candidate value} except possibly the last span in a slot which can be of shorter duration.  One example is given below with two slots where b(l)=11101100001100 according to the SS configuration (blue symbol means there is MO configuration) assuming (X,Y)=(4,3). Then the span pattern is illustrated in red and repeated in every slot. It is clear that the time separation between any two spans including across the slots to see if the gap is larger or equal to X=4 symbols, which means it satisfy the (X,Y) requirement. In this example, X=4 symbols, Y=3 symbols and M=14 symbols where it is clear that M is larger than X.  cid:image001.png@01D6FAEC.971219A0  Then if we extend X to be multiple slots, with similar mechanism, M should be defined where the span pattern is repeated and M > X. If we consider M slots as a slot group, the span gap should be checked between any two spans within or across the slot group. |
| Ericsson | * Agree with Intel and Samsung's comments. * I also think it is important that we discuss at the same time about what is the capability within a slot for Alt-1 and Alt-3. Hence I think the following FFS should be added at the end:   + FFS: Capability definition within a slot * An important aspect of Alt-1 is that BD/CCEs are not counted only within a slot group and not across slot groups * For Alt-2, I think vivo has done a nice job explaining how Rel-15 works. At least I have a better understanding now of where the concept of "repeating" pattern comes from. So I think if the intention of Alt-2 is to be like the Rel-16 span concept, then there needs to be some further clarifications of Alt-2. I'm not sure the FFS is worded accurately "…including cases where a span is longer than one slot or crosses a slot boundary". Isn't the notion of "crossing a slot boundary" like vivo describes " the span gap should be checked between any two spans within or across the slot group."?   I have done some editing for clarity using Alex's proposal above as a baseline, also including Intel and Samsung's suggestions, the FFS I mention above, plus the fix for Alt-1. I have not made an attempt to solve any issues with Alt-2 as mentioned above.  Proposed modification of agreement:  Choose one of the following alternatives for defining the multi-slot PDCCH monitoring capability   * Alt 1: Use a fixed pattern of slots within a slot group as the baseline to define the new capability.   + Each slot group consists of X slots   + Slot groups are consecutive and non-overlapping   + The capability indicates the BD/CCE budget within Y consecutive slots in each slot group and not across slot groups.   + FFS: Supported values/constraints of X and Y, e.g. Y<=X, Y=X   + FFS: Restrictions on location of the Y slots within a slot group, e.g. the Y slots always start at the first slot within a slot group   + FFS: Capability definition within a slot * Alt 2: Use an (X,Y) span as the baseline to define the new capability   + X is the minimum time separation between the start of two consecutive spans   + The capability indicates the BD/CCE budget within a span of Y consecutive [symbols or slots]   + Y <= X   + FFS: Exact values of X and Y and units in which they are defined (e.g., symbols, slots), including cases where a span is longer than one slot or crosses a slot boundary. * Alt 3: Use a sliding window of X slots as the baseline to define the new capability.   + The capability indicates the BD/CCE budget within the sliding window   + The sliding unit of the sliding window is [1] slot.   + FFS: Capability definition within a slot * Specific numbers for X, Y may depend on UE capability and gNB configuration   + Examples:     - X = [4] slots for 480 kHz SCS and X = [8] slots for 960 kHz SCS |
| LG Electronics | Agree with the proposed modification of agreement from Moderator in principle.  For Alt-1, we prefer to keep [symbols or slots] as is and to modify FFS according to the comments from MediaTek. As far as we know, there was no consensus that Y should be in unit of slot.  For Alt-2, we agree with Apple and vivo to keep the FFS on repetition issue. We think that whether number of slots within which the span pattern is repeated is needed can be discussed together with defining the multi-slot PDCCH monitoring capability in Alt-2. In addition, agree with Samsung’s suggestion. |
| Lenovo, Motorola Mobility | Generally, Ericsson updates seem fine to us. We are further open to consider adding FFS in Alt-2 for span pattern repetition.  But for Alt-1, not sure if we already need to agree that slots as units are applied and capability will be defined per slot. |
| Nokia, NSB | The latest proposal by Ericsson is generally ok, but we agree with Apple in keeping [symbols or slots]. We see this more as a signaling aspect and if the group later decides that a raster of 14 symbols is sufficient, we can revise the decision accordingly. Correspondingly, the FFS point on “Capability definition within a slot” would not be needed at least yet. |
| ZTE, Sanechips | For Alt1 from Moderator’s suggestion, we think that it it not clear for “in a slot group”, such wording seems to imply PDCCH monitoring pattern is fix in a slot group while not fix in different slot groups. In our understanding, fixed pattern should be applicable to different slot groups.  Besides, we have some doubts about parameter Y. If Y represents the first Y slots of a slot group, whether it means any symbols of first Y slots need to be monitored by UE. Or just monitor first Y slot, but specific number of symbol and location of PDCCH monitroing are FFS.  For Alt1 from Ericsson’s update, we think new add “not across slot groups” is not necessary, because BD/CCE budget have clearly limited within Y consectutive slots in each slot group, which means it is not feasible across slot gourps. Besides, the same problem as our mentioned in previous two paragragh, we think fixed pattern should be for different slot groups. Thus, the following update for main bullet in Alt1 should be supported:   * Alt 1: Use a fixed pattern in slot groups as the baseline to define the new capability.   + Each slot group consists of X slots   + Slot groups are consecutive and non-overlapping   + The capability indicates the BD/CCE budget within Y consecutive [symbols or slots] in each slot group   + FFS: Supported values/constraints of X and Y, e.g. Y<=X, Y=X   + FFS: Restrictions on location of the Y [symbols or slots] within a slot group, e.g. the Y [symbols or slots] always start at the first symbol of the first slot within a slot group |