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Title: Slice-based cell re-selection algorithm

Document for: Discussion and TP

# 1 Introduction

In this document, we show how slice-based cell re-selection can be implemented in the UE with minimal impact to current standard, and avoiding multiple repetitions of cell re-selection while ensuring that all available frequencies are searched in the case when UE has bad coverage.

# 2 Discussion

## 2.1 Slice based Cell re-selection with minimal UE impact

In current cell re-selection procedure, the UE will use the cell reselection priorities received from the network to decide what frequencies to measure on and search for suitable cells. If radio conditions are good at current cell, the UE will measure on frequencies with higher priorities. If no suitable cell is found on higher prioritized frequencies, the UE will stay in current cell and continue to search for a suitable cell on higher prioritized frequencies as long as the UE is in IDLE or INACTIVE.

If the radio conditions on current frequency are insufficient, the UE will search for a suitable cell on all frequencies with cell reselection priorities, to ensure that the UE will find coverage if possible. If no suitable cell is found, the UE will stay in current cell and continue to search for a suitable cell on all frequencies as long as the UE is in IDLE or INACTIVE.

Note that it is not stated in the standard in what order the frequencies are measured, even though it can be expected that when the UE enters IDLE or INACTIVE, it would start measuring on the highest prioritized frequency. However, once the UE is camping on the highest prioritized frequency where a suitable cell was found, it will regularly measure on all frequencies with higher priority than the current cell in an unspecified order.

In the TP in the running TP for 38.304 [1], it is described that the UE is supposed to first do cell re-selection based on slice specific frequency priorities for the highest prioritized slice, and then cell re-selection based on the legacy re-selection priorities.

If also other slices with lower priority is to be taken into account, extra iterations of cell re-selection are needed with these priorities. There are several problems with this method. Since cell-reselection is a process that will continue until a suitable cell is found, the slice-based cell-reselection will not exit when no suitable cell is found. In order to ensure that also legacy reselection is performed, the proposal could be modified with a timer specifying when the re-selection should be exited, or it could be stated that the frequencies are only measured once before the legacy priorities are used. Also it would have to be stated when slice based re-selection should be repeated if no suitable cell was found with the legacy priorities.

1. The cell re-selection procedure as currently described in draft running CR to TS38.304 does not correctly cover the fallback from slice-based cell re-selection to legacy cell re-selection.

Another problem is that probably there would be frequencies with both slice specific and legacy priorities, causing extra measurements on these frequencies, or special UE functionality to avoid extra measurements.

All these problems can be avoided, if the same principles are used for Slice-based cell re-selection as in legacy cell re-selection.. That is, the cell reselection function in the UE should be provided with reselection priorities for all frequencies that are available for it in the network, and the cell re-selection is performed as today. This can be achieved if the UE before cell re-selection calculates a new set of reselection priorities based on both the legacy and the slice specific frequency priorities.

In Appendix A, a TP for 38.304 is included, which shows how this can be described.

1. We ask RAN2 to agree that Slice Based Cell re-selection, just as in legacy, shall be based on reselection priorities for all frequencies that the UE may use. The priorities used may be called ‘SliceBasedReselectionPriorities’.
2. We ask RAN2 to accept the TP in Appendix A.

## 2.2 Algorithms for Calculation of Slice based Cell re-selection priorities

### 2.2.1 Cell reselection based on the highest prioritized slice supported on a frequency

It has been agreed that Solution 4 is used as a baseline for the work item. In the RAN2#15-e agreements it is stated (Solution 4):

**The following steps are used for slice based cell (re)selection in AS:**

**Step 0: NAS layer at UE provides slice information to AS layer at UE, including slice priorities.**

**Step 1: AS sorts slices in priority order starting with highest priority slice.**

**Step 2: Select slices in priority order starting with the highest priority slice.**

**Step 3: For the selected slice assign priority to frequencies received from network.**

**Step 4: Starting with the highest priority frequency, perform measurements (same as legacy).**

**Step 5: If the highest ranked cell is suitable (as defined in 38.304) and supports the selected slice in step 2 then camp on the cell and exit this sequence of operation; FFS: How the UE determines whether the highest ranked cell supports the selected slice.**

**Step 6: If there are remaining frequencies then go back to step 4.**

**Step 7: FFS: If the end of the slice list has not been reached go back to step 2.**

**Step 8: Perform legacy cell reselection.**

To ensure the same behaviour with one set of frequency priorities, frequencies supporting the highest priority slice should get higher priority than all other frequencies, and of the remaining frequencies, these supporting the second highest slice should have higher priority than all other frequencies etc. Frequencies not supporting any of the prioritized slices should have the lowest priorities, ordered based on the legacy cell reselection priority.

If the slice priority is in the range of 1 to P, where 1 is the lowest priority and P the highest, this behaviour can be achieved if the SliceBasedReselectionPriority for each frequency is calculated as:

SliceBasedReselectionPriority = slicePriority \* MaxReselectionPriorityValue + frequencyPriority,

Where slicePriority is the priority of the highest priority slice supported on the frequency, MaxReselectionPriorityValue is a constant which is higher than the maximum reselection priority and frequencyPriority is the slice Specific Frequency Priority of that slice on the frequency, or the legacy cellReselectionPriority if no prioritized slice is supported on the frequency.

As an example, if the reselection priorities are in the range of 0-9, the MaxReselectionPriorityValue can be set to 10, and using this formula, frequencies not supporting any of the slices will have priorities in the range of 0-9, frequencies only supporting the lowest priority slice with priority 1,will have priorities 10-19, etc.

In Appendix B, a TP is included that describes this algorithm.

### 2.2.2 Cell reselection based on all slices supported on a frequency

Several companies have raised concern about solution 4, since even if there is a frequency supporting all used slices, the solution will only base the cell reselection on the highest prioritized slice. That is, if one slice support all slices in the slice list, and another frequency only supports the one with highest priority, the frequency supporting all slices should be selected. However, with in solution 2, the frequency with highest slice specific frequency priority for the top priority slice will be selected, and support of other slices will not be taken into account.

We share these concerns, and think that the wanted behaviour is that among the frequencies supporting the highest prioritizes slice, the UE should prioritize frequencies also supporting the second highest prioritized slice, and among frequencies supporting the two highest prioritized slices, frequencies also supporting the slice with third highest priority should be prioritized, etc.

When the cell selection is based on a set of SliceBasedReselectionPriorities, the complexity of the algorithm calculating the priorities will only have negligible impact on the cell reselection delays. Therefore, more complex algorithms may be used, in order to get the wanted behaviour of the cell re-selection. In this section an alternative algorithm is described that ensures that UE will reselect to a frequency supporting as many as possible of the high priority slices. In section 2.2.3, an algorithm is described that can be used if several slices have the same priority.

In order to base the cell reselection on not only the highest priority slice, the slicePriority variable in section 2.2.1 can be calculated as a bitmap of slice support for the prioritized slices in priority order. The SliceBasedReselectionPriority can then be calculated using the same formula as in section 2.2.1.

In table 1 below, an example is show for how the slicePriority is calculated for 5 frequencies A-E. First the slices are listed in priority order, and the slice support per frequency is included in the table. The slicePriority is derived as the bitmap of the slice support, and at last, it is transferred to a digital value.

|  |  |  |
| --- | --- | --- |
|  |  | **Frequency** |
| **Priority** | **Slice** | **A** | **B** | **C** | **D** | **E** |
| 6 | c | X | - | X | - | - |
| 5 | a | - | - | X | - | - |
| 4 | d | X | - | - | - | - |
| 3 | b | X | X | - | X | - |
| 2 | e | - | - | - | - | - |
| 1 | f | X | X | - | X | - |
| **slicePriority (binary)** | 101101  | 000101 | 110000 | 000101  | 000000 |
| **slicePriority (digital)**  | 45 | 5 | 48 | 5 | 0 |

Table 1: Example calculation of slicePriority. The resulting priority order for cell reselection is frequency C, A, B and D, E. Which of the frequencies B and D that will get highest reselection priority depends on the values of the Slice Based Reselection Priorities for slice b.

### 2.2.3 Priority based on all supported slices – if several slices may have same priority

When the slice priority is a separate variable, and not the order in a slice list, it is possible to use the same priority value for several slices. This can be useful in case there are slices that may be needed by the user with similar probability.

In that case, it should be agreed how the UE should prioritize frequencies supporting one or several of slices with same priority. In this section we show how the algorithm can be designed if the wanted behaviour is that for slices with the same priority, the frequency should primarily be prioritized based on number of slices with that priority that it supports. For frequencies supporting the same number of slices, the priority should be based on the maximum of the slice specific frequency priorities.

This behaviour can be achieved, if the slice support bit in the solution above is replaced with the number of slices supported with the priority level. Assuming that the total number of slices is less than 9, one digital digit could be used for each slice priority level, and the numbers could be concatenated similarly as shown above, but in the digital domain. However, this method will give unnecessary large reselection priority values. Lower values can be achieved if the slicePriority is calculated in the digital domain, but more than one bit is needed when there is more than one slice with the same priority. An example is shown in table 2.

First, in row number 1-3 the slices and the slice specific frequency priorities are listed for each slice priority level. In row 4-6 the number of supported slices with each priority level is given in binary form. In row 7, the binary numbers are concatenated to form the slicePriority for each frequency. The values are transferred to digital form.

In row 8 a frequencyPriority is derived for each frequency. For frequency A and B it is the slice specific reselection priority of slice a, and for frequency C, the value for slice f is used, since that is the slice supported on the frequency. On frequency D both slice a and f are supported, so the value used is the maximum of the slice specific priorities for these slices. For frequency E, no slice is supported, so the legacy cell reselection priority is use.

Finaly in row 9, the Slice based reselection priority is calculated, using the formula:

**slicePriority\*10 + frequencyPriority** (the frequency priorities are in the range of 0-9)

|  |  |  |
| --- | --- | --- |
| Row number |  | Frequency |
| Slice prio | Slices | A | B | C | D | E |
| 1 | 3 | a, f | 7, - | 4, - | -, 3 | 6, 5 | - |
| 2 | 2 | b, c, e | 5, -, 3 | 2, -, - | 3, 4, 3 | -, 6, - | -, -, - |
| 3 | 1 | d | 5 | 2 | - | 7 | - |
| 4 | Slices(prio 3) *binary* | 01  | 01 | 01 | 10 | 00 |
| 5 | Slices(prio 2) *binary*  | 10  | 01 | 11 | 01 | 00 |
| 6 | Slices(prio 1) *binary*  | 1 | 1 | 0 | 1 | 0 |
| 7 | **slicePriority** *binary=>digital* | 01101=>13 | 01011=>11 | 01110=>14 | 10011=>19 | 00000=>0 |
| 8 | **frequencyPriority** | **7** | **4** | **3** | **6** | **2 (legacy)** |
| 9 | **Slice based resel. priority** | **137** | **114** | **143** | **196** | **2** |

Table 2: Example calculation of Combined reselect priorities. The resulting priority order for cell reselection is frequency D, C, A, B, E.

### 2.2.4 Selection of Algorithm for frequency prioritization.

Above three algorithms have been described which can be used for calculating the slice based frequency priorities. All algorithms ensure that cell re-selection may be performed on all frequencies available to the UE, but the behaviour varies depending on how much details of the slices supported on the frequencies are taken into account.

Note that even though some of the algorithm may be complex to understand, it can be implemented in the UE with fast matrix operations, and will typically only be performed once in each cell the UE is camping in. Therefor the computation time is negligible.

1. RAN2 should select the algorithm for deriving the SliceBasedReselectionPriority based on the wanted cell re-selection behaviour. There is no need to take algorithm complexity into account, since re-selection performance is not impacted.
2. We ask RAN2 to discuss what behaviour is preferred for Slice Based Cell re-selection and agree on the algorithm for calculating the SliceBasedReselectionPriorities.

## 2.3 Checking if target cell supports the wanted slices.

After a target slice is selected, using slice based cell re-selection, the slice support of the slice should be evaluated. This evaluation should be done at the same time as other criteria for inter-frequency cell-reselection are evaluated. Therefor we think that it should be covered in section 5.2.4.5 of the 38.304 spec.

In order to decide if the UE should reselect to a cell when the slice support information is not as expected, a new frequency priority should be calculated. A new section could be used to describe how this is done. In Appendix C a TP is shown for section 5.2.4.5 and in Appendix D we present example text for a new section that describes how to recalculate the frequency priority if solution 4 is used.

1. We ask RAN2 to accept the TP in Appendix C.
2. A new section is used to describe the calculation of a temporary reselection priority. The content of that section depends on what algorithm is selected for calculating the frequency SliceBasedReselectionPriorities.

# Conclusion

Based on the discussion in the previous sections we make the following observation:

. Observation 1 The cell re-selection procedure as currently described in draft running CR to TS38.304 does not correctly cover the fallback from slice-based cell re-selection to legacy cell re-selection.

Observation 2 RAN2 should select the algorithm for deriving the SliceBasedReselectionPriority based on the wanted cell re-selection behaviour. There is no need to take algorithm complexity into account, since re-selection performance is not impacted.

Based on the discussion in the previous sections we propose the following:

[Proposal 1 We ask RAN2 to agree that Slice Based Cell re-selection, just as in legacy, shall be based on reselection priorities for all frequencies that the UE may use. The priorities used may be called ‘SliceBasedReselectionPriorities’.](#_Toc85782813)

[Proposal 2 We ask RAN2 to accept the TP in Appendix A.](#_Toc85782814)

[Proposal 3 We ask RAN2 to discuss what behaviour is preferred for Slice Based Cell re-selection and agree on the algorithm for calculating the SliceBasedReselectionPriorities.](#_Toc85782815)

[Proposal 4 We ask RAN2 to accept the TP in Appendix C.](#_Toc85782816)

[Proposal 5 A new section is used to describe the calculation of a temporary reselection priority. The content of that section depends on what algorithm is selected for calculating the frequency SliceBasedReselectionPriorities.](#_Toc85782817)

# References

[1] Email\_Discusson/RAN2/[RAN2#115-e]/[Post115-e][246][Slicing] Running 38.304 CR for RAN slicing (CMCC): draft 38304CR for slicing\_v15\_Clean for submission.doc

# Appendix A TEXT PROPOSAL for 38.304 section 5.2.4.1

### 5.2.4 Cell Reselection evaluation process

#### 5.2.4.1 Reselection priorities handling

Absolute priorities of different NR frequencies or inter-RAT frequencies may be provided to the UE in the system information, in the *RRCRelease* message, or by inheriting from another RAT at inter-RAT cell (re)selection. In the case of system information, an NR frequency or inter-RAT frequency may be listed without providing a priority (i.e. the field *cellReselectionPriority* is absent for that frequency). If priorities are provided in dedicated signalling, the UE shall ignore all the priorities provided in system information. including slice or slice group specific frequency priorities If UE is in *camped on any cell* state, UE shall only apply the priorities provided by system information from current cell, and the UE preserves priorities provided by dedicated signalling and *deprioritisationReq* received in *RRCRelease* unless specified otherwise. When the UE in camped normally state, has only dedicated priorities other than for the current frequency, the UE shall consider the current frequency to be the lowest priority frequency (i.e. lower than any of the network configured values).

If the UE is configured to perform both NR sidelink communication and V2X sidelink communication, the UE may consider the frequency providing both NR sidelink communication configuration and V2X sidelink communication configuration to be the highest priority. If the UE is configured to perform NR sidelink communication and not perform V2X communication, the UE may consider the frequency providing NR sidelink communication configuration to be the highest priority. If the UE is configured to perform V2X sidelink communication and not perform NR sidelink communication, the UE may consider the frequency providing V2X sidelink communication configuration to be the highest priority.

For a UE supporting slice-based cell reselection, if the UE is provided with slice priorities from NAS, and if slice or slice group specific frequency priorities are included in the cell reselection information used by the UE, UE calculates cell reselection priorities for each frequency, as defined in 5.2.4.x.

NOTE 1: The frequency only providing the anchor frequency configuration should not be prioritized for V2X service during cell reselection, as specified in TS 38.331[3].

NOTE 2: When UE is configured to perform NR sidelink communication or V2X sidelink communication performs cell reselection, it may consider the frequencies providing the intra-carrier and inter-carrier configuration have equal priority in cell reselection.

NOTE 3: The prioritization among the frequencies which UE considers to be the highest priority frequency is left to UE implementation.

NOTE 4: The UE is configured to perform V2X sidelink communication or NR sidelink communication, if it has the capability and is authorized for the corresponding sidelink operation.

NOTE 5: When UE is configured to perform both NR sidelink communication and V2X sidelink communication, but cannot find a frequency which can provide both NR sidelink communication configuration and V2X sidelink communication configuration, UE may consider the frequency providing either NR sidelink communication configuration or V2X sidelink communication configuration to be the highest priority.

The UE shall only perform cell reselection evaluation for NR frequencies and inter-RAT frequencies that are given in system information and for which the UE has a priority provided.

In case UE receives *RRCRelease* with *deprioritisationReq*, UE shall consider current frequency and stored frequencies due to the previously received *RRCRelease* with *deprioritisationReq* or all the frequencies of NR to be the lowest priority frequency (i.e. lower than any of the network configured values) while T325 is running irrespective of camped RAT. The UE shall delete the stored deprioritisation request(s) when a PLMN selection or SNPN selection is performed on request by NAS (TS 23.122 [9]).

NOTE: UE should search for a higher priority layer for cell reselection as soon as possible after the change of priority. The minimum related performance requirements specified in TS 38.133 [8] are still applicable.

The UE shall delete priorities provided by dedicated signalling when:

- the UE enters a different RRC state; or

- the optional validity time of dedicated priorities (T320) expires; or

- the UE receives an *RRCRelease* message with the field *cellReselectionPriorities* absent; or

- a PLMN selection or SNPN selection is performed on request by NAS (TS 23.122 [9]).

NOTE 2: Equal priorities between RATs are not supported.

The UE shall not consider any black listed cells as candidate for cell reselection.

The UE shall consider only the white listed cells, if configured, as candidates for cell reselection.

The UE in RRC\_IDLE state shall inherit the priorities provided by dedicated signalling and the remaining validity time (i.e. T320 in NR and E-UTRA), if configured, at inter-RAT cell (re)selection.

NOTE 3: The network may assign dedicated cell reselection priorities for frequencies not configured by system information.

# Appendix B Example Text Proposal, for 38.304: Calculation of SliceBasedReselectionPriority.

5.2.4.X Calculation of SliceBasedReselectionPriority

For each slice in the slice list received from NAS, the *SliceSpecificFrequencyPriority* is the *sliceSpecificFrequencyPriority* signalled for the slice group of the slice.

For frequencies with a slice specific frequency priority for at least one slice in the slice list, the reselection priority for the frequency is calculated by the formula:

 SlicePriority \* MaxReselectionPriorityValue + SliceReselectionPriority,

where SlicePriority is the priority of the highest prioritized slice for which the UE have received *SliceSpecificFrequencyPriority* on the frequency. MaxReselectionPriorityValue is a constant which is higher than the maximum reselection priority, and SliceReselectionPriority is the *SliceSpecificReselectionPriority* of the highest prioritized slice on the frequency.

For frequencies with no slice specific frequency priority for any slice included in the slice list received from NAS, the Slice Based Reselection Priority is set to the *CellReselectionPriority* of the frequency.

# Appendix C Text Proposal for 38.304: Evaluating Slice support in cell

#### 5.2.4.5 NR Inter-frequency and inter-RAT Cell Reselection criteria

If *threshServingLowQ* is broadcast in system information and more than 1 second has elapsed since the UE camped on the current serving cell, cell reselection to a cell on a higher priority NR frequency or inter-RAT frequency than the serving frequency shall be performed if:

- A cell of a higher priority NR or EUTRAN RAT/frequency fulfils Squal > ThreshX, HighQ during a time interval TreselectionRAT

Otherwise, cell reselection to a cell on a higher priority NR frequency or inter-RAT frequency than the serving frequency shall be performed if:

- A cell of a higher priority RAT/ frequency fulfils Srxlev > ThreshX, HighP during a time interval TreselectionRAT; and

- More than 1 second has elapsed since the UE camped on the current serving cell.

Cell reselection to a cell on an equal priority NR frequency shall be based on ranking for intra-frequency cell reselection as defined in clause 5.2.4.6.

If *threshServingLowQ* is broadcast in system information and more than 1 second has elapsed since the UE camped on the current serving cell, cell reselection to a cell on a lower priority NR frequency or inter-RAT frequency than the serving frequency shall be performed if:

- The serving cell fulfils Squal < ThreshServing, LowQ and a cell of a lower priority NR or E-UTRAN RAT/ frequency fulfils Squal > ThreshX, LowQ during a time interval TreselectionRAT.

Otherwise, cell reselection to a cell on a lower priority NR frequency or inter-RAT frequency than the serving frequency shall be performed if:

- The serving cell fulfils Srxlev < ThreshServing, LowP and a cell of a lower priority RAT/ frequency fulfils Srxlev > ThreshX, LowP during a time interval TreselectionRAT; and

- More than 1 second has elapsed since the UE camped on the current serving cell.

If the UE is supporting slice-based cell reselection, and one or more cells fulfil the above criteria for cell reselection, and the frequencies have a SliceBasedFrequencyPriority above MaxReselectionPriorityValue, the UE shall evaluate the slice support of these cell(s). If an evaluated cell does not support the same slices as given in the slice information for the frequency, the UE shall calculate a TemporaryReselectionPriority for the frequency, as described in section 5.2.4.y. If the TemporaryReselectionPriority is not valid, or a cell with such temporary priority does not fulfil the above criteria for cell reselection, the UE shall not consider this cell as a candidate for cell reselection. The temporary priority shall be used as reselection priority for this frequency until the highest ranked cell changes on the frequency, or new slice priorities are received from NAS.

If one or more cells fulfil the above criteria for cell reselection, and the frequencies have a frequency priority above MaxReselectionPriorityValue, the UE shall evaluate the slice support of these cell(s). If an evaluated cell does not support the slice group used to calculate the frequency priority for the frequency the UE shall start using the *CellReselectionPriority* for that frequency if any, and the UE should not use the slice-based priorities for this frequency for 300 seconds or until it receives new slice priority information.

NOTE: If there is no *CellReselectionPriority* for the frequency, or a cell with the *CellReselectionPriority* of the frequency does not fulfil the above criteria for cell reselection, the UE will not consider this cell as a candidate for cell reselection.

Editor's Note: FFS: How the UE evaluates the slice support of the selected slices.

Cell reselection to a higher priority RAT/frequency shall take precedence over a lower priority RAT/frequency if multiple cells of different priorities fulfil the cell reselection criteria.

If more than one cell meets the above criteria, the UE shall reselect a cell as follows:

- If the highest-priority frequency is an NR frequency, the highest ranked cell among the cells on the highest priority frequency(ies) meeting the criteria according to clause 5.2.4.6;

- If the highest-priority frequency is from another RAT, the strongest cell among the cells on the highest priority frequency(ies) meeting the criteria of that RAT.

# Appendix D Example Text Proposal for 38.304: Calculation of TemporaryReselectionPriority

5.2.4.Y Calculation of TemporaryReselectionPriority with slice support information for a cell.

If the slice support of the highest ranked cell on a frequency is known, and it is not the same as advertised for the frequency, a TemporaryReselectionPriority is calculated that is valid for the frequency as long as the cell is highest ranked.

For frequencies supporting as least one slice in the slice list with a slice specific frequency priority, the TemporaryReselectionPriority is calculated by the formula:

TemporaryReselectionPriority = SlicePriority \* MaxReselectionPriorityValue + SliceReselectionPriority,

where SlicePriority is the priority of the highest prioritized slice that the cell supports, and for which the UE have received *SliceSpecificFrequencyPriority* on the frequency, and SliceReselectionPriority is the *SliceSpecificReselectionPriority* of that slice.

If the cell does not support any slice in the slice list with a *SliceSpecificFrequencyPriority:*

* If there is a *CellReselectionPriority* for the frequency, the TemporaryReselectionPriority is set to the *CellReselectionPriority* of the frequency.
* If there is no *CellReselectionPriority* for the frequency, the TemporaryReselectionPriority is set to invalid.