3GPP TSG-RAN WG2 #116e R2-21xxxxx

Electronic meeting, November 1st – 12th 2021

Agenda Item: 9.1.3

Source: Ericsson

Title: [Post115-e][302] [NBIOT/eMTC R17] carrier selection (Ericsson)

Document for: Discussion, Decision

# 1 Introduction

This document is to gather input from companies for below email discussion:

* [post115-e][302] [NBIOT/eMTC R17] carrier selection (Ericsson)

Scope: progress open issues, main aim is to converge on option 1c vs. 2a for decision in next meeting.

Intended outcome: Report to next meeting

Deadline: long

The two options are listed below

* Option 1c: Network enables UE to select a Rel-17 paging carrier by providing the coverage information (CEL/Rmax) for the carrier selection to the UE in dedicated signalling
* Option 2a: NW indicates the carrier to use explicitly via dedicated signalling based on information determined within the NW.

# 2 Contact Information

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| Qualcomm | Mungal Dhanda (mdhanda@qi.qualcomm.com) |
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# 3 Discussion

RAN2 has been discussing the two options below for paging carrier selection,

* Option 1c: Network enables UE to select a Rel-17 paging carrier by providing the coverage information (CEL/Rmax) for the carrier selection to the UE in dedicated signalling
* Option 2a: NW indicates the carrier to use explicitly via dedicated signalling based on information determined within the NW.

There are different views regarding which of these options should be specified. Let’s have a look at the commonalities and differences.

In option 1c, the eNB provides an Rmax/CEL value to the UE so that the UE can select a paging carrier based on such value when it is released to idle mode. In option 2a, the eNB maps the UE directly to a paging carrier by indicating the paging carrier explicitly. This is in principle quite similar in both options. In option 1c there has to be also additional means for the network to indicate which paging carrier should the UE select in case there are multiple paging carrier with the same Rmax/CEL value.

Another similarity between these two Options is the sort of information that needs to be signalled between the eNB and the MME as part of the paging information container. For option 1c, it would be the Rmax/CEL value and for option 2a it is the paging carrier.

Once the UE is in idle mode monitoring the paging carrier as indicated by the network explicitly (as in option 2a) or implicitly (as in option 1c), there has to be means for the UE to check whether its coverage has stayed the same since it has been released to idle mode. Otherwise, the UE would not know whether it is time for the UE to reconsider its selection for the paging carrier. RAN2 has agreed that UE metric for determining carrier suitability and selection is based on NRSRP and a hysteresis/longer averaging/timer is used such UE metric based on NRSRP. It has also been agreed that whenever this criterion is met paging carrier as indicated by the network explicitly or implicitly is used, otherwise the UE should use the fallback mechanism.

Note that upon cell change RAN2 has agreed on two alternatives for option 1c and for option 2a UE performs the fallback to the legacy mechanism.

In the rest of this document, these two options are discussed with respect to the following aspects

* Impact on paging strategy
* Load Balancing
* Exception case handling (deletion, addition or change of carrier)
* Specification and Implementation Complexity

## 3.1 Impact on paging strategy

For option 1c there are two alternatives to consider when cell change happens, as mentioned above. These alternatives are Alt 1 UE to select a paging carrier based on previously determined “coverage level” and broadcasted paging carrier configuration in the new cell, and Alt 2 fallback mechanism. It has been claimed that Alt 1 will be beneficial, especially if the UE happens to be in the same or better coverage with respect to the previous cell since there will not be any need for fallback and the UE would continue to monitor the paging carrier with the same Rmax/CEL. On the other hand, it has also been claimed that such flexibility for the UE makes it challenging for the network to predict which paging carrier the UE may be monitoring and thus have an impact on the network paging strategy. Yet another claim was that cells may have different coverage (Tx power, CE levels, quality interference) and thus it may not be suitable to use the Rmax/CEL value determined in the previous cell to determine the paging carrier in the new cell.

For option 2a and Alt2 for option 1c, fallback mechanism is performed, which is the legacy paging carrier mechanism based on UE\_ID.

Q1: Companies are requested to provide feedback regarding the impact of these two alternatives for Option 1c on the paging strategy mechanism.

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| Company name | Comments |
| Qualcomm | The main issue with Alt 1 (i.e., after reselection paging carrier selected based on previously determined coverage level) for option 1c is how can the network know that when a UE reselects to a new cell that it will monitor coverage-based paging carrier or legacy paging carrier? As we have pointed out in the past, network will have to first page on coverage-based paging carriers in the neighbour cells and if no response then page on legacy paging carriers in the neighbour cells (or alterntively page on both legacy and coverage-based paging carriers in the neighbour cells). In the end there is high probability that more paging resources will be used in the neighbour cells compared to legacy UEs. The end result is not only MT performance for UEs supporting coverage-based paging carrier will degrade but it will also impact legacy UEs due to increased paging carrier usage.  Therefore, we see far more disadvantages with Alt 1 compared to Alt 2 (i.e., fallback). Furthermore, as Alt 2 is already agreed for option 2, selecting Alt 2 for option 1c makes one more commonality between the two options.  We conclude Alt 2 is the sensible way forward for option 1c. |
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**Summary: TBD**

## 3.2 Load Balancing

There has been no consensus on which option would provide means for the network to perform a uniform distribution of UEs to paging carriers.

In option 1c, the eNB and the UE would know which carrier to use or to monitor for paging messages based on the following formula in TS 36.304

floor(UE\_ID/(N\*Ns)) mod W < W(0) + W(1) + … + W(n)

In option 2a, the eNB would allocate a paging carrier to the UE when it is released to idle mode. In both options, it would be up to the network to make sure that UEs are uniformly distributed to the paging carriers as UEs would simply monitor the allocated paging carrier. Basically:

In Option 1c; the above formula needs to be computed by both eNB and individual UE and in option 2a it would be performed only by eNB.

One should also consider the mobile UEs moving in between cells which would make it harder for the network to maintain a uniform distribution unless UEs coming from neighbouring cells monitor legacy paging carriers based on UE\_IDs, i.e., use fallback mechanism, after cell reselection.

Q2: Companies are requested to illustrate the load balancing solution, how option 1c and option 2a can perform load balancing. Please elaborate on whether there is any difference between options when performance on uniform distribution is considered and what are pros/cons of each option with respect to load balancing.

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| Company name | Comments |
| Qualcomm | The underlying principle is that coverage-based paging carrier will provide lower coverage in a cell than legacy paging carriers because legacy paging carriers are designed to cover the entire cell. For this reason, we consider distributing UEs amongst legacy paging carriers and coverage-based paging carrriers (unlike the case of distributing UEs amongst anchor paging carrier and legacy non-anchor paging carrriers) is a lower priority. A coverage-based paging carrier can carry more paging occasions than a legacy paging carrier due to the fact that coverage-based paging carrier uses fewer repetitions (e.g., a factor of 2 more paging occasions) therefore, relatively speaking, a coverage-based paging carrier can support more UEs.  Even if all the popluation of UEs in a cell support coverage-based paging carriers, it is highly unlikely that all UEs will be in a coverage level to use the coverage-based paging carriers hence there will be a natural distribution of UEs amongts coverage-based paging carriers and legacy paging carriers. Remember, at least the anchor paging carrier has to cover the entire cell.  As with legacy paging carriers, if network finds that too many UEs are selecting coverage-based paging carrier over legacy paging carrier then network has two options:   1. Add more coverage based paging carriers. 2. Adjust coverage level of the coverage-based paging carrier to reduce the number of UEs it is suitable for in a cell.   The UE/eNB can consider all the coverage-based paging carriers that are suitable for UE’s coverage level then UE/eNB can use the legacy scheme to select one paging carrier from this list of coverage-based paging carriers (similar to the way a UE/eNB creates a sub-list of GWUS supporting paging paging carriers. If DRX is also considered then UE creates a sub-sub-list that has carrier-specific DRX no shorter than UE specific DRX. UE then selects one paging carrier from the sub-list or (the sub-sub list if DRX is of interest) according to the weights for each paging carrier in the list.  The above aproach can be used with both option 1c and option 2a hence there is no real difference in load balancing. |
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**Summary: TBD**

In actual network deployments when the number of users grow in a certain area, additional carrier may be required. The additional carrier generally has similar characteristics as compared to the deployed carrier. Hence, it is expected that different carriers may be configured with same Rmax value, especially if the network assumes/knows that there are many UEs, which have camped in the cell, that happen to be in similar coverage. In such case how will the network ensure that UEs are distributed uniformly.

Q3: Companies are requested to illustrate the load balancing solution, how option 1c and option 2a can perform load balancing in that case; i.e., if another paging carrier is added with similar characteristics; e.g. same Rmax due to capacity concerns.

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| Company name | Load Balancing Steps |
| Qualcomm | If there are N coverage-based paging carriers that meet the UE’s coverage level then legacy scheme can be used to select one paging carrier amongst this sub-set (i.e., based on weights for each of the paging carriers in the set and UE ID). |
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## 3.3 Exception case handling (deletion or change of carrier)

In this section we consider the scenario when network releases, adds or changes the configuration of a paging carrier so that the associated Rmax/CEL value changes.

For option 1c, it has been stated that the network can reconfigure the paging carriers with respect to their Rmax/CEL values so that the UEs would select accordingly once update takes place, i.e., after system information update notification. For option 2a, it has been stated that such update can be conveyed to the UEs with no need to change the carriers assigned to the UEs, but rather using pointers that are mapped to the actual carriers using a mapping table broadcast as part of system information.

Q4: Companies are requested to provide their view on exception case handling; e.g. when an assigned or selected carrier is deleted. Is there any benefit/drawback for any of the options (1c, 2a) and why?

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| Company name | Comments |
| Qualcomm | Changing paging carrier configuration is a rare event and is generally done with care due to the impact it can have on UE reachability.  Option 1c: Use legacy scheme for handling change in paging carrier configuration. If none of the coverage-based paging carriers in the new configuration are suitable then UE falls back to legacy paging carrier selection scheme.  Option 2a: If new paging carrier configuration has a carrier associated with the carrier index UE is using and it is suitable then UE continues to use the corresponding paging carrier. Otherwise UE falls back to legacy paging carrier selection scheme.  With both options, suitable means that coverage level is right and DRX cycle is right. |
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Summary: TBD

Another aspect to consider is when a new paging carrier with power boosting is added, an existing paging carrier is power boosted or a power boosted paging carrier is released.

Q5 Companies are requested to provide their views regarding how scenarios mentioned above are handled for option 1c and option 2a.

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| Company name | Comments |
| Qualcomm | How can UE know whether a particular paging carrier is power boosted or not? We don’t think power-boosting can be considred in either of the two options. UE can not know what is the reason for power-boosting a particular paging carrier. |
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## 3.4 Specification and Implementation complexity

Regarding the specification and implementation impacts, it is mainly the specification effort and UE/eNB implementation that needs to be considered.

Based upon the discussion so far, the paging carrier selection would be influenced by two key factors:

a) Rmax

b) DRX

Companies are requested to provide their input on the specification details such as TS 36.304 paging carrier formula update based upon their preferred option.

TS 36.304 Current Paging formula

floor(UE\_ID/(N\*Ns)) mod W < W(0) + W(1) + … + W(n)

How would the above Rmax and DRX based selection would be accommodated by the above formula. What updates are needed; if any?

Q6: Companies are requested to provide details of formula update needed to support each of their preferred option or can also provide for both options?

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| Company name | TS 36.304 Specification Impact Details |
| Qualcomm | For both options, we don’t think there is any need to change this formula. Specification needs to define how the sub-list of paging carriers is constructed from which the UE is to select a coverage-based paging carrier. This in our view is similar to the way the sub-list is constructed for GWUS. |
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Q7: Companies are requested to give input on the steps that UE would need to perform for the carrier selection considering multiple factors such as Rmax and DRX and describe the UE implementation effort/complexity level for their preferred option or can also provide for both options?

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| Company name | Comments |
| Qualcomm | Option 1c:  Step 1: UE constructs a list of coverage-based paging carriers that meet the UEs coverage level (e.g., if UE’s coverage level is X then all coverage-based paging carriers with configured coverage level >=X are candidates).  Step 2: If UE is configured with UE specific DRX, then from the list constructed in step 1, UE constructs a list of all paging carriers with carrier specific DRX >= UE specific DRX. Otherwise it is the complete list from Step 1.  Step 3: If UE intends to use GWUS then UE selectes all coverage-based paging carriers that are configured with GWUS from the list of paging carrier list constructed in step 2. If UE does not intend to use GWUS or none of the paging carriers in paging carrier list constructed in step 2 is configured with GWUS then it is the complete list from step 2.  Step 4: UE uses the legacy formula to select one paging carrier, for the coverage-based paging carrier list from step 3.  Option 2a: We think same steps as for option 1c can be used by eNB for option 2.  In general, the eNB implementation is likely to be same for both option 1c (to match UE steps) and 2a.  From spec perspective, we don’t think it is too complex to implement option 1c but it is clear option 1c will need clear spec while with option 2a it is left to eNB implementation. |
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Q8: Companies are requested to give input on the steps that eNB would need to perform the carrier selection considering multiple factors such as Rmax and DRX and describe the eNB implementation effort/complexity level for their preferred option or can also provide for both options?

Note: Of-course eNB implementation is not standardized here it is more to understand some steps that would be needed to gauge some complexity involved.

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| Company name | Comments |
| Qualcomm | See response to Q7. |
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Q9: Companies are requested to give an opinion based upon answer of above 3 questions regarding the complexity comparison between option 1c and option 2a. Please provide any additional comments as deemed necessary. Which option has less complexity?

* Option 1c
* Option 2a

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| Company name | Which option has less complexity | Comments |
| Qualcomm | Option 2a | From specification and UE implementation perspective option 2 is simpler. But in our view that only postpones the critical issue of how to determine the most suitable coverage-based paging carrier to eNB implementation. |
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## 3.5 Other

Please provide any other input or other pros/cons for both options, if any.

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| Company name | Comments |
| Qualcomm | Technically both option 1c and 2a are feasible but in our view the underlying issue is to ensure the coverage-based paging carrier UE ends up using is suitable for the UE and should not require UE to frequently switch between coverage-based paging carrier and legacy paging carrier. |
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Summary: TBD

# 4 Conclusion

This paper focused on comparion of coverage based paging carrier selection option 1c and option 2a . Corresponding proposals are listed as follows:

TBD