**3GPP TSG RAN WG2 NR #104 Meeting** **R2-1816829**

**Spokane, US, 12th - 16th November 2018**

**Agenda Item:** **11.2.1.1**

**Source:** **ZTE**

**Title:** **Considerations on 4-step RACH procedure for NR-U**

**Document for:** **Discussion and Decision**

# 1 Introduction

In RAN2 #103 [1], the following agreement is reached.

> ⇒ R2 assumes that RACH may be enhanced by additional opportunities, e.g. in time or frequency domain, FFS which messages the additional opportunities apply to.
>
> ⇒ Will study the model of single-RACH procedure. FFS multiple parallel procedure model
>
> ⇒ Will study impact to *PREAMBLE_TRANSMISSION_COUNTER*, *PREAMBLE_POWER_RAMPING_COUNTER*, ra-ResponseWindow, ra-ContentionResolutionTimer

In RAN2 #103bis[2], the agreement on preamble transmission is reached as follows.

> Agreements:
> 1. Power ramping is not applied when preamble is not transmitted due to LBT failure.
> 2. Discuss at next meeting to decide on whether *PREAMBLE_TRANSMISSION_COUNTER* should always be increased independently on the outcome of LBT

In RAN1 #94bis[3], the agreement on potential RACH resource enhancements was reached as follows.

> Agreement:
>
> Following options have been identified for potential RACH resource enhancements in NR-U beyond the flexibility already available in Rel-15:
>
> **1. Frequency-domain enhancement**
>
> a. Multiple PRACH resources across multiple LBT sub-bands/carriers for both contention-free and contention-based RA
>
> **2. Time-domain enhancements**
>
> a. For connected mode UE, scheduling of PRACH resources via DCI.
>
> i. Triggered PRACH within TXOP can use a new resource
>
> b. For idle mode UE, scheduling of PRACH resources via paging
>
> i. Note: potential inefficiency in network resource due to paging across multiple cells
>
> c. Additional, new RACH resources are used immediately following detection of DRS transmission
>
> d. Multiple PRACH transmissions before Msg2 reception in RAR window for initial access
>
> i. Number of allowed transmissions is pre-defined or indicated, e.g., in RMSI
>
> ii. FFS: How to handle potential multiple RARs to same UE
>
> e. Group wise SSB-to-RO mapping by frequency first-time second manner, where grouping is in time domain

In this contribution, according to the agreements form the past RAN1 and RAN2, we will proceed to discuss some enhancements on 4-step RACH procedure, and provide our proposals.

# 2 Discussion

For NR-U, since LBT needs to be performed before transmitting each message, each message may subject to LBT failure. It influences the random access delay, such that control plane requirement will not be met. Therefore, for each message, some enhancements should be considered in order to reduce access delay.

**Proposal 1:** *each message of RACH procedure needs to be enhanced for NR-U.*

## 2.1 Frequency domain enhancements

### 2.1.1 Multiple BWPs

**Initial access procedure**

In RAN1 #93[4], the agreement on the bandwidth of initial active DL/UL BWP was reached as follows.

Agreement:

- Initial active DL/UL BWP is approximately 20MHz for 5GHz band
    - The final value will be quantized to number of PRBs
- Initial active DL/UL BWP is approximately 20MHz for 6GHz band if similar channelization as 5GHz band is used for 6GHz band
- FFS: Initial active DL/UL BWP for other applicable bands, including 60GHz

According to the agreement above, for 5GHz and 6GHz, initial active DL/UL BWP is approximately 20MHz. Since the minimal bandwidth unit of performing LBT is also 20MHz, only one LBT is performed in initial active DL/UL BWP for initial access procedure. Therefore, additional frequency domain opportunities need to be considered for initial access.

**Observation 1:** *Additional frequency domain opportunities need to be considered for initial access.*

In RAN #78, the agreement on channel bandwidth was reached as follows.

For all NR bands below 6 GHz, all bandwidths listed in TS 38.101-1 v15.0.0 Table 5.3.5-1 for each band shall be mandatory with a single CC.

Channel bandwidths added in future versions will be discussed separately

Based on the agreement and all bandwidths listed in [5], for band n77(3.3GHz-4.2GHz), n78(3.3GHz-3.8GHz) and n79(4.4GHz-5GHz), UE needs to support 100MHz bandwidth. For 6GHz band, we think similar channelization as 5GHz band may be used for 6GHz band. Therefore UE might need to support 100MHz for 6GHz band as well. Based on UE capability, multiple BWPs may be configured to UE via RMSI, and each configured BWP may be configured with RACH resources. It is similar to the configuration in RRC_CONNECTED.

For Msg1 transmission, UE may attempt to perform LBT in each BWP with RACH resource. Once one LBT succeeds, UE may perform Msg1 transmission. Since each BWP channel status is independent, it may increase the probability of LBT success.

For Msg3 enhancement, gNB may allocate multiple grants corresponding to different BWPs, then indicate to UE via Msg2 or dynamic grant for Msg3 retransmission. When UE receives multiple grants, it may attempt to perform LBT in each indicated BWP. Once one LBT succeeds, UE may perform Msg3 transmission.

For Msg2/Msg4 enhancement, gNB may attempt to perform LBT in multiple BWPs. Once one LBT succeeds, gNB may perform Msg2/Msg4 transmission. UE will monitor PDCCH in each configured DL BWP.

**Proposal 2:** *For each message in initial access procedure, some frequency domain enhancements need to be considered, such as multiple BWPs.*

**RACH procedure in RRC_CONNECTED**

In NR, multiple BWPs may be configured to UE via RRC message, and each BWP may be configured with RACH resources. However, only a BWP is active at any time. For NR-U, when multiple BWPs are configured, and each BWP is configured with RACH resources. If UE performs LBTs in multiple BWPs and performs transmission in the BWP where LBT succeeds, multiple active BWPs should be supported to avoid the BWP switch delay. Some details are analyzed in [6].

Similar to each message enhancement with multiple BWPs in initial access procedure, LBT is performed in each of the multiple BWPs. Once one LBT succeeds for a specific BWP, UE/gNB performs transmission in the BWP.

**Proposal 3:** *For each message of RACH procedure in RRC_CONNECTED, frequency domain enhancements need to be considered, such as multiple BWPs.*

### 2.1.2 Multiple carriers

In RAN1 #94bis, the agreement on frequency domain enhancement was reached as follows.

Following options have been identified for potential RACH resource enhancements in NR-U beyond the flexibility already available in Rel-15:

***Frequency-domain enhancement***

*Multiple PRACH resources across multiple LBT sub-bands/carriers for both contention-free and contention-based RA*

If multiple PRACH resource across multiple carriers for contention-based RA are configured to UE, LBT may be performed in multiple carriers. It may increase the probability of LBT success. Meanwhile, it also means preamble may be transmitted in any cell with PRACH resource. For CA, it means preamble may be transmitted on SCells for CBRA. Then CBRA on SCell needs to be supported.

However, in RAN2 #103bis, the agreement that only CFRA on SCell was supported was reached, which is not consistent with RAN1's agreement. From RAN1 perspective, mulitple RPACH resource across multiple carriers for CBRA are beneficial for frequency domain enhancement. Therefore, in order to align with RAN1 agreement, both CBRA and CFRA on SCell should be supported from RAN2 perspective.

**Proposal 4:** *Both CBRA and CFRA on SCell should be supported.*

## 2.2 Time domain enhancement

In RAN1 #94bis, the agreement on the time domain enhancement on preamble transmission for initial access was reached as follows.

*Multiple PRACH transmissions before Msg2 reception in RAR window for initial access*

*Number of allowed transmissions is pre-defined or indicated, e.g., in RMSI*

According to the agreement, multiple Msg1 transmissions in time domain may be performed before Msg2 reception in RAR window for initial access. It implies multiple RACH occasions may be attempted, and it increases the probability of LBT success. However, impact of multiple Msg1 transmissions on RAN2 specification needs to be further studied.

**Proposal 5:** *Impact of multiple Msg1 transmissions on RAN2 specification needs to be further studied.*

For Msg3 enhancements in time domain, multiple transmission opportunities or repetition may be configured to UE. When UE receives MAC RAR or dynamic grant for Msg3 retransmission, it can attempt multiple LBTs until LBT succeeds in the candidate transmission resources.

**Proposal 6:** *Some time domain enhancements on Msg3 need to be considered, e.g. multiple transmission opportunities, multiple repetition.*

## 2.3 Preamble transmission counter

According to the RAN1 and RAN2 agreement, when LBT fails for preamble transmission, power ramping counter will not be incremented. However, the MAC layer is not aware of the LBT outcome. Then in order to suspend the power ramping, the physical layer needs to indicate the LBT outcome to the MAC layer. And some detailed analysis in [7].

**Proposal 7:** *LBT outcome should be indicated to the MAC layer.*

In addition, whether or not *PREAMBLE_TRANSMISSION_COUNTER* is incremented due to LBT failure needs to be further discussed from RAN2 perspective. If *PREAMBLE_TRANSMISSION_COUNTER* is incremented, it may incur unnecessary RLF. Of course, one direct solution is to configure larger max preamble transmission number. However, when channel condition is poor, it will increase random access delay. So, it is not a good option configuring larger preamble transmission number. If *PREAMBLE_TRANSMISSION_COUNTER* is not incremented when LBT fails for preamble transmission, RLF will not be triggered unnecessarily. Therefore, *PREAMBLE_TRANSMISSION_COUNTER* should not be incremented due to LBT failure.

**Proposal 8:** *When preamble transmission is blocked due to LBT failure, PREAMBLE_TRANSMISSION_COUNTER should not be incremented.*

If preamble transmission counter is not incremented, when channel is very busy, UE may have no chance to access the channel for a long time. So some ways to trigger recovery from LBT failures need to be considered. For example, the MAC layer may count consecutive LBT failure times. When consecutive LBT failure times for preamble transmission exceed a certain value, UE may terminate the current RACH procedure and select other carrier, i.e. in this case, MAC should indicate random access failure to upper layer, then the upper layer initiates reestablishment procedure. Once a preamble transmission happens, LBT failure counter should be reset.

**Proposal 9:** *When consecutive LBT failure times exceed a certain value, MAC terminates the current RACH procedure and indicates random access failure to upper layer.*

### 2.4 Impact on RAR window

In NR, the MAC layer indicates lower layer to transmit preamble using the selected PRACH resource. Once the MAC layer indicates the transmission, it will start *ra-ResponseWindow* at the first PDCCH occasion from the end of Random Access Preamble transmission. However, for NR-U, Preamble transmission can only happen when LBT succeeds. When LBT fails, there is no need for UE to start *ra-ResponseWindow* to wait for Random Access Response. Therefore, when LBT failure outcome is indicated to the MAC layer, it may perform transmission in the next RACH occasion as soon as possible.

**Proposal 10:** *When preamble transmission is blocked due to LBT failure, RAR window should not be started.*

### 2.5 impact on contention resolution timer

In NR, MAC specification description on Msg3 transmission is as follows in [8].

> Once Msg3 is transmitted, the MAC entity shall:
>
> 1> start the *ra-ContentionResolutionTimer* and restart the *ra-ContentionResolutionTimer* at each HARQ retransmission in the first symbol after the end of the Msg3 transmission;
>
> 1> monitor the PDCCH while the *ra-ContentionResolutionTimer* is running regardless of the possible occurrence of a measurement gap;

According to the specification description above, once Msg3 is transmitted, the MAC layer will start and restart *ra-ContentionResolutionTimer*, and monitor PDCCH to wait to receive Msg3 grant or Msg4 within the timer. Here, once Msg3 is indicated to the physical layer, transmission is considered to happen. However, for NR-U, Msg3 transmission may subject to LBT failure, such that transmission cannot be performed. For this case, whether or not *ra-ContentionResolutionTimer* is started and restarted needs to be considered.

For NR-U, when Msg3 transmission is blocked due to LBT failure, UE will wait for Msg3 grant to perform Msg3 retransmission. If UE does not start or restart *ra-ContentionResolutionTimer*, it will not know how long it should wait for Msg3 grant. When the channel is busy for gNB to transmit a new Msg3 grant, UE may wait for Msg3 grant all the time, and this procedure will not be terminated. Therefore, when Msg3 transmission fails due to LBT, UE will also start and restart *ra-ContentionResolutionTimer* to wait to receive Msg3 grant to perform Msg3 retransmission.

**Proposal 11:** *Contention resolution timer should be started/restarted regardless of LBT outcome.*

## 3 Conclusion

In this contribution, we discussed random access procedure in NR-U, and have made the following proposals.

**Proposal 1:** *each message of RACH procedure needs to be enhanced for NR-U.*

**Observation 1:** *Additional frequency domain opportunities need to be considered for initial access.*

**Proposal 2:** *For each message in initial access procedure, some frequency domain enhancements need to be considered, such as multiple BWPs.*

**Proposal 3:** *For each message of RACH procedure in RRC_CONNECTED, frequency domain enhancements need to be considered, such as multiple BWPs.*

**Proposal 4:** *Both CBRA and CFRA on SCell should be supported..*

**Proposal 5:** *Impact of multiple Msg1 transmissions on RAN2 specification needs to be further studied.*

**Proposal 6:** *Some time enhancements on Msg3 need to be considered, e.g. multiple transmission opportunities, multiple repetition.*

**Proposal 7:** *LBT outcome should be indicated to the MAC layer.*

**Proposal 8:** *When preamble transmission is blocked due to LBT failure, PREAMBLE_TRANSMISSION_COUNTER should not be incremented.*

**Proposal 9:** *When consecutive LBT failure times exceed a certain value, MAC terminates the current RACH procedure and indicates random access failure to upper layer.*

**Proposal 10:** *When preamble transmission is blocked due to LBT failure, RAR window should not be started.*

**Proposal 11:** *Contention resolution timer should be started/restarted regardless of LBT outcome.*

# 4 Reference


[1] Draft_RAN2#103_Report_v1, Gothenburg, Sweden, 20th - 24th Aug 2018.

[2] Draft_RAN2#103bis_Report_v1, Chengdu, China, 8th-12th Oct 2018.

[3] Draft_Minutes_report_RAN1#94b_v010, Chengdu, China, 8th-12th Oct 2018.

[4] Final_Minutes_report_RAN1#93_v100, Busan, Korea, 21st – 25th, May2018.

[5] 38.101 f30.

[6] R2-18xxxxx Considerations on BWP for NR-U.

[7] R2-18xxxxx LBT outcome indication.

[8] 38.321 f30.


# 5 Text Proposal

### 7.2.2.2.1 RACH (4-step, 2-step)

NR-U will support contention-free RACH (CFRA) and contention-based RACH (CBRA). On SpCells and SCells, ~~only CFRA is supported while~~ both CBRA and CFRA are supported ~~on SpCells~~.

Both 4-step and 2-step RACH will be supported for NR-U. Here 2-step RACH refers to the procedure which can complete CBRA in two steps. One additional benefit of 2-step RACH is due to less LBT impact with the reduced number of messages. However, in order to alleviate the impact of LBT failures further, additional opportunities for the RACH messages may be introduced, e.g. in time or frequency domain, for both 4-step and 2-step RACH. For frequency domain opportunities, multiple BWPs/carriers may be considered. For time domain opportunities, taking 4-step as an example, multiple Msg1 are transmitted before Msg2 reception in RAR window, and impact of multiple Msg1 transmissions on specification needs to be further studied. For Msg3, multiple repetition or multiple transmission opportunities may be used. For Msg4, gNB may attempt transmissions in multiple time domain resources. In addition, all the RACH triggers for legacy 4-step procedure may also be applicable to 2-step procedure.

For 4-step RACH, the messages in time order are named as msg1, msg2, msg3, msg4 and for 2-step RACH, they are named msgA and msgB.

A single RACH procedure is assumed as a baseline while the need for multiple procedures can be investigated further.

As a baseline, the random-access response to msg1 will be on SpCell and msg3 is assumed to use a predetermined HARQ ID.

In legacy RACH, the counters for preamble transmission and power ramping are increased with every attempt. In NR-U, power ramping is not applied when preamble is not transmitted due to LBT failure. This will require an indication from the physical layer to the MAC.

Besides, When preamble is not transmitted due to LBT failure, preamble transmission counter should not be incremented. However, when channel is busy for a long time, RACH procedure may not be terminated in time. So MAC layer may count LBT failure times. When LBT failure times exceed a threshold, the MAC entity indicates random access failure to the upper layer. In addition, for this case, RAR window should not be started in order to perform the next attempt of transmission as soon as possible.



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