

Agenda item: 8.8.2
Source: Sequans Communications
Title: Considerations on skipping UL padding transmissions
Document for: Discussion and Decision

1. Introduction

In RAN#71, the work item [1] was agreed. The objective of this work item is to specify L2 latency enhancements as identified in RAN2:

- Introduction of short SPS period to allow UL prescheduling
- Reduction of padding in case of dynamic and SPS based UL pre-scheduling to reduce interference and UE power consumption
- Further discussion and, if concluded, introduction of feedback for SPS activation, reactivation and deactivation command

From the study item [2], the reduction of padding can be achieved by allowing the UE to skip padding transmissions in grant if there is no UL data in the UE buffer.

In this document, we highlight possible issues of such scheme and propose a way forward.

2. Discussion

2.1. Impacts of skipping UL padding transmissions

In legacy LTE UL scheduling, there is no possibility for a UE to skip PUSCH transmissions. New transmissions are scheduled through dynamic or configured (periodic) grant, whereas HARQ retransmissions are scheduled through dynamic UL grant (adaptive retransmissions) or PHICH NACK indication (non-adaptive retransmissions). Moreover, there is no data-associated UL control information (TBS, MCS, HARQ process ID, NDI, RV) as this information is basically indicated by the scheduling (or implicitly derived). The eNB has all the UCI required to process the UE transmission. It can always assume that the UE has transmitted the PUSCH as intended, and use received PUSCH to update power control loop, adaptive modulation and coding (link adaptation), or timing advance.

By allowing skipping of PUSCH transmissions, the eNB can no longer assume that the UE has performed the scheduled transmission as expected.

PUSCH transmission probability in UL grant

In the “fast uplink” access use cases, the UE is configured with a short UL SPS periodicity (1ms), and skipping of UL padding transmission is allowed. Most of the time, it will actually not perform any transmission. In a way, PUSCH transmissions in that case can be considered as “unsolicited” (the eNB does not know in advance that there is an actual PUSCH transmission), whereas legacy PUSCH transmissions can be considered as “solicited” (the eNB knows there is a PUSCH transmission, it is mandatory for the UE to transmit).

The issue can be easily understood by looking at the probability to have a PUSCH transmitted on a given UL grant, as shown in Table 1.

Table 1

Use Case	Legacy operation		“Fast uplink” Short SPS, 1ms periodicity
	Dynamic grant	Configured grant	
PUSCH transmission probability in UL grant	99% (~10 ⁻² PDCCH loss rate)	100%	2% (Assuming 1 packet/50ms)

PUSCH detection at eNB

It could be argued that the eNB can detect PUSCH transmissions, for instance based on energy detection or DMRS detection. This can be challenging as:

- Setting a too low detection threshold can result in having a high false detection rate (noise or other UE interferences detected as PUSCH)
- Setting a high detection threshold can result in a severe loss in UL sensitivity

This is something which is for instance also required in LAA UL. However, it should be understood that the PUSCH detection is far more challenging for “fast uplink” use case. Given a normalized false detection rate/RB, p , the final false detection rate will scale as:

$$p * (1 - \text{PUSCH transmission probability in UL grant}) / \text{number of RBs in PUSCH transmission}$$

The Table 2 compares the typical false detection error rate in UL LAA and “fast uplink” use cases.

Table 2

Use Case	UL LAA	“Fast uplink”
Number of RBs in PUSCH transmission	~20 RBs	~2RBs
PUSCH transmission probability in UL grant	~50% (depends of LBT)	2%
False detection rate	0.025 * p	0.49 * p

As it can be seen, it is expected that due to very low PUSCH transmission bandwidth and low PUSCH transmission probability, reliable PUSCH detection will be challenging in “fast uplink” use case. In our understanding, RAN2 should not assume this can be realized at eNB without system impacts. This would actually fall into RAN1 scope, and if this needs to be assumed, we think RAN2 should consider consulting RAN1 on this topic.

Observation 1: PUSCH detection at eNB could be challenging for “fast uplink” use case, and should not be assumed to provide enough reliability

Possible impacts of skipping UL transmissions

Skipping UL transmissions is a fundamental change from legacy operation, and the impacts should be carefully reviewed. We see the possible following impacts:

- HARQ
 - eNB may not be able to reliably perform PUSCH DTX detection. This would lead to soft buffer being corrupted by noise samples. A consequence can be that HARQ is no longer possible. A very conservative MCS may need to be used.
- Power control/link adaptation

- In case of SPS, PUSCH can be used to adjust power transmission on a short term basis, while PUSCH statistics can be used to adapt the MCS (coding rate). This is no longer possible and as a result, a more conservative MCS may need to be configured. Periodic SRS could be configured as well, however this is not really adapted to SPS use case (it is more adapted to frequency-selective scheduling), and not well adapted to very small bandwidths (minimum SRS BW is 4RBs, and starting RBs are multiple of 4). Moreover, it would consume additional resources.
- PDCCH
 - No systematic PUSCH transmission also means no confirmation that a PDCCH indicating an UL grant (dynamic, or for SPS configuration/release) was correctly received. Hence this may also impact downlink aggregation level configuration algorithm.
- UL lost recovery
 - There is currently no specific UE-triggered action when PUSCH does not go through. It is expected that in that case, the eNB can take appropriate action since it has full knowledge of the UL issue. However, this would no longer be possible.
- Implicit SPS release
 - As noted during the SI, the implicit release mechanism whereby the UE autonomously releases the configured SPS resources after N successive UL padding transmissions is no longer applicable.

2.2. Control of skipping UL padding transmissions

As shown in previous section, skipping all UL padding transmissions may have important system impacts, compared to legacy operation where skipping UL transmission is never allowed.

A compromise would be for the eNB to have more control on skipping UL padding transmissions: instead of always allowing the UE to skip such transmissions, this could be authorized under additional conditions.

During the study phase, it has already been noted that performing transmissions from time to time could be beneficial. A proposal was made in [3] to use a prohibit timer, started when an UL padding transmission is performed. In our view, this may still be inefficient as the eNB cannot know with accuracy when the UE is expected to perform an UL transmission (since it may not decode the first UL padding transmission from the UE). These transmissions would remain unsolicited.

We believe that a scheme in which the UE can perform solicited transmissions (i.e. mandatory transmissions in UL grant) at instants known by the eNB, during what could be called “legacy operation occasions”, would be more useful. This would basically enable the eNB to use the same adaptation algorithm as in legacy operation, while still keeping the benefits of skipping UL most of the time.

For dynamic grants, an indication could be added in the DCI to indicate whether UL skipping is allowed or not for a given UL grant. However, this would not be possible for configured grants.

The most straightforward way to implement this could be to configure the UE with a “DTX pattern”, based on a subframe offset in a similar way as the existing C-DRX pattern. The ON periods of such pattern can be used to define “legacy operation occasions”: skipping UL would be allowed only in OFF periods, whereas during ON periods UE needs to obey UL grants as in legacy. Same mechanism can be used both for configured grants or dynamic grants. It can also be considered to align the DTX pattern with the C-DRX pattern in order to minimize the power consumption and the signaling impact. This is illustrated in Figure 1.

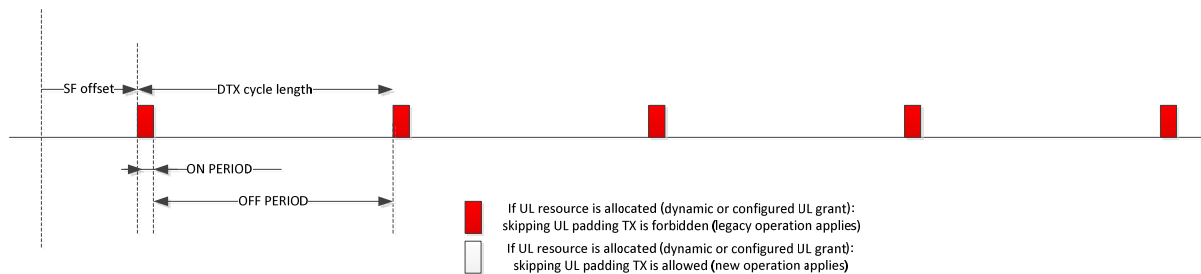


Figure 1

Typically, a periodicity of 40ms with a ON duration of 1ms could be used, as this would match the typical pattern used for VoLTE, but larger periodicity may be considered to limit power consumption impact.

It can be noted that the existing periodic reports, such as periodic PHR or periodic BSR, cannot be used to reliably predict the transmissions of the UE since they are related to an initial UE initiated report which may not be received by the eNB.

Hence, we make the following proposal:

Proposal 1: RAN2 should discuss introducing “legacy operation occasions” where “skipping UL padding transmissions” is not allowed, e.g. based on a DTX pattern configured by the eNB

2.3. Power Headroom Reporting

The Power Headroom Reporting procedure is normally used during UL transfer to inform the eNB about the difference between the nominal UE maximum transmit power and the estimated power of PUSCH transmission.

In current specification [4] 5.4.6, a Power Headroom Report (PHR) has several possible triggers. One of the possible trigger is the expiration of *periodicPHR-Timer*, which is used to provide periodical PHR to the NW.

Once triggered, PHR is sent in a TTI as soon as UL resources are allocated. In legacy operation, UL resources are basically allocated when there is UL data to be sent. In this case it makes sense to have PHR sent. When there is no UL data to be sent (e.g., DL only during some time, end of a TX speech burst in VoLTE, ...), triggered PHR are actually not transmitted.

If skipping of UL padding transmission is enabled, it is not clear if PHR would be sent when no UL data is sent. It depends whether “skipping UL padding transmission” encompasses also transmissions with PHR.

- On the one hand, this may not be needed as this is not done in legacy operation.
- On the other hand, as already discussed, this may be considered useful in the sense that it provides periodic UL transmissions which can help maintaining the UL (for instance, if *periodicPHR-Timer* is configured, PHR will be sent at least periodically).

As a baseline, since it does not appear to be useful when no UL data is sent, it would make sense to avoid sending PHR when skip UL padding is enabled and no UL data is sent. This provides further UE power consumption and UL interference reduction.

Proposal 2a: RAN2 should discuss whether to not send PHR when skip UL padding is enabled and no UL data is to be sent

A possible efficient compromise would be to combine PHR transmission with the DTX pattern in proposal 1. More specifically, the UE could skip sending PHR when no UL data is sent during OFF periods of a DTX pattern. However, during ON periods (“legacy operation occasions”), the UE would obey legacy requirements and transmit PHR, if any was triggered previously. This has the benefits of both periodic eNB-aware UL transmissions, and reported PHR., which can be used by the eNB to reconfigure the configured grant if needed (power update/MCS update).

Proposal 2b: RAN2 should consider using “legacy operation occasions” to allow transmission of a triggered PHR

2.4. Buffer Status Reporting

The Buffer Status Reporting procedure is used to inform the eNB about the amount of data to be sent in the UE UL buffers. Among the possible buffer status reports, “Regular BSR” is used when there is UL data to transmit, and may trigger a SR procedure when there is no allocated resources, while “Periodic BSR” is used independently of UL data, does not trigger SR and is sent only when there are allocated resources.

The “Periodic BSR” is triggered based on *periodicBSR-Timer* expiry, which is restarted each time a BSR is sent. In “fast uplink” use case, there are always allocated resources. Such a “Periodic BSR” may be triggered and sent periodically, even when there is no UL data in UE buffer. However, it is not clear whether this behaviour is desirable.

- On the one hand, sending a Periodic BSR when there is no UL data to be sent appears useless
- On the other hand, it is desirable to keep “Periodic BSR” functionality, for instance to handle correctly data transfer bursts occurring during

As a baseline, since it does not appear to be useful when no UL data is sent, it would make sense to avoid sending periodic BSR when skip UL padding is enabled and no UL data is to be sent. This provides further UE power consumption and UL interference reduction.

Proposal 3a: RAN2 should discuss whether to not send periodic BSR when skip UL padding is enabled and no UL data is to be sent

However, as it is still desirable to keep “Periodic BSR” functionality, an efficient compromise could be to have such periodic BSRs transmitted as part of “legacy operation occasions”. This has the benefits of both periodic eNB-aware UL transmissions, and reported periodic BSR.

Proposal 3b: RAN2 should consider using “legacy operation occasions” to allow transmission of a triggered periodic BSR

2.5. UL lost handling

The UL lost recovery issue was not raised during the study item, and we think it should be studied further, especially in case proposal 1 is not agreed. It is interesting to check what is the UE behavior when UL connection is lost – for instance, because the UE has moved towards the edge of the cell. It can also be due to the time alignment being lost.

In legacy operation, when UE needs to transmit UL data, there are basically two cases:

- **No scheduled resources available:** UE uses SR (if time aligned) or PRACH (if not time aligned). In both cases, UE will notify upper layers in case of failure. Typically, a SR procedure failure will trigger a PRACH procedure, and a PRACH procedure failure will trigger a radio link failure procedure from RRC.
 - The eNB is not aware that UE is transmitting. Hence, failure handling is important at UE side to solve the issue.
- **Scheduled resources available:** UE can transmit data on PUSCH. The eNB is responsible for requesting HARQ retransmissions when required. However, in case where the maximum number of HARQ retransmissions is reached on UE side, there is no specific action at MAC level. The transmission goes on with a new transport block. RLC AM bearers will eventually reach maximum number of retransmissions, and trigger a RLF. But if there are only RLC UM bearer(s), then no RLF is triggered at all.
 - The eNB is aware that UE is transmitting. Hence, failure handling is less important at UE side since eNB can detect UL issues and take appropriate actions

With configured UL grant every subframe, UE is always in the “scheduled resources available” use case and does not use SR procedure. Instead, PUSCH is used. If skipping of UL padding transmission is enabled, the eNB is not aware that UE is transmitting. If UL is lost, eNB will not take any action since it is unaware of it. And in current specification, UE won’t either. In case RLC UM bearer is used, the UE may go on transmitting till TAT expiry (which is expected to be set to a high value, possibly infinity, in order to avoid unneeded timing advance updates).

The proposal 1 would solve the issue, as eNB would notice that UL is lost by no longer decoding solicited PUSCH on “legacy operation occasions”.

Alternatively, especially if it is no agreed to introduce “legacy operation occasions”, it can be discussed whether MAC shall take any specific action when unsolicited PUSCH transmissions (i.e., PUSCH transmissions while skip UL padding transmission is allowed) do not go through. A possible option is that, after a given number of unsuccessful unsolicited PUSCH transmissions, the UE autonomously release the “skipping UL padding transmission” enabled SPS resources. It would then fallback to legacy operation (SR, PRACH, RLF procedures). The SR/PRACH may be an indication to the eNB that the UE has released the SPS resources. The eNB can then recover the situation and allocate appropriate resource to the UE.

In case dynamic grants are used for pre-scheduling, it is assumed that this would not be on a per-TTI/long term basis. Hence, the issue of unsolicited PUSCH transmissions not seen by the eNB may be less critical. Indeed, the UE can be expected to still send some SRs, which could be detected by the eNB.

The way UE can determine unsolicited PUSCH transmissions issue depends on the agreed scheme for HARQ feedback. PHICH is strongly encoded, and the NACK-ACK errors are expected to be low. Alternatively, ACK feedback through PDCCH can provide more reliability in the determination that PUSCH transmission was successful..

Proposal 4: RAN2 should discuss whether to take any action on unsolicited PUSCH transmission issues

It has been noted during the study item that the existing implicit release of SPS resources after N successive UL padding transmissions is no longer applicable. In our view, having a mechanism to implicitly release the SPS resources could also be useful to mitigate UL lost issue impact. It should be also noted that once SPS is configured by RRC, it could be accidentally started on a false PDCCH detection, in which case the eNB is not even aware a UE is transmitting (on a randomly selected resource). At least in legacy operation, the configured resource would be released once UE has no UL data to send. But this would not be the case with new operation. A possible solution would be to limit the number of pre-allocated resources to a given amount M (fixed or configured) – or equivalently to release the configured resource after M successive period.

Proposal 5: RAN2 should discuss whether the UE should autonomously release the configured resource, after a specified duration (or number of resources) from the activation

3. Conclusion

In this contribution, we have discussed possible impacts of skipping UL padding transmissions, and made the following proposals:

Observation 1: PUSCH detection at eNB could be challenging for “fast uplink” use case, and should not be assumed to provide enough reliabilit

Proposal 1: RAN2 should discuss introducing “legacy operation occasions” where “skipping UL padding transmissions” is not allowed, e.g. based on a DTX pattern configured by the eNB

Proposal 2a: RAN2 should discuss whether to not send PHR when skip UL padding is enabled and no UL data is to be sent

Proposal 2b: RAN2 should consider using “legacy operation occasions” to allow transmission of a triggered PHR

Proposal 3a: RAN2 should discuss whether to not send periodic BSR when skip UL padding is enabled and no UL data is to be sent

Proposal 3b: RAN2 should consider using “legacy operation occasions” to allow transmission of a triggered periodic BSR

Proposal 4: RAN2 should discuss whether to take any action on unsolicited PUSCH transmission issues

Proposal 5: RAN2 should discuss whether the UE should autonomously release the configured resource, after a specified duration (or number of resources) from the activation

References

- [1] RP-160667, “*New WI proposal: L2 latency reduction techniques for LTE*”, Ericsson
- [2] R2-157181, 3GPP TR 36.881 V0.5.0
- [3] R2-153222. Potential protocol enhancement for Fast uplink access, Nokia.
- [4] 3GPP TS 36.321 V13.0.0 (2015-12)