

Agenda item: 7.11
Source: Huawei, HiSilicon
Title: Uplink latency reduction for synchronized UEs
Document for: Discussion and Decision

1 Introduction

In RAN#67, a new Study Item on “Latency reduction techniques for LTE” [1] was approved, and one of the objectives is to study “Fast uplink access solutions” in RAN2. More specially:

- *for active UEs and UEs that have been inactive a longer time, but are kept in RRC Connected, focus should be on reducing user plane latency for the scheduled UL transmission and getting a more resource efficient solution with protocol and signaling enhancements, compared to the pre-scheduling solutions allowed by the standard today, both with and without preserving the current TTI length and processing times;*

In this contribution, we will first analyze the problems of the pre-scheduling solution. Then, we will discuss possible solutions to reduce the uplink transmission latency for active UEs (i.e. synchronized UEs), and to address the problems of the pre-scheduling solution.

2 Discussion

2.1 Problems of the pre-scheduling solution

The pre-scheduling solution is a mechanism that allowed by the standard today. As analyzed in [2], in order to achieve the latency reduction gain, the pre-scheduling period should be less than 10ms for the pre-scheduling solution. However, with a short pre-scheduling period, the PDCCH resources and the PUSCH resources might be significantly wasted. Assuming the UL packets inter-arrival time is 40ms in average and each packet consumes one PDCCH and one PUSCH, then with the 1ms pre-scheduling period, 40 PDCCH and 40 PUSCH will be consumed for only one uplink packet. It is obviously that the uplink latency reduction benefit caused by 1ms pre-scheduling period can't justify the corresponding radio resource waste. In case the system load is high, it is doubtful whether the pre-scheduling solution with 1ms period is still feasible.

For the pre-scheduling solution, according to the current specification, the UE will anyway send something e.g. Padding and/or Padding BSR on the pre-scheduled uplink resources even though there is no valid data to transmit. This will cause unnecessary UE battery consumption as well as unnecessary uplink interference.

Observation: The pre-scheduling solution with small period has the following problems:

- Significant PDCCH overhead
- Unnecessary uplink PUSCH resource waste
- Unnecessary uplink interference
- Unnecessary UE battery consumption

2.2 Solutions to reduce the PDCCH overhead

2.2.1 UL SPS with reduced interval

To reduce the PDCCH overhead for the pre-scheduling solution, one possible solution is to use the current SPS scheme. However, in the current specification, the minimum UL SPS interval is 10ms which cannot achieve the latency reduction purpose compared to the existing non-pre-scheduled transmission (i.e. DSR based). One straightforward way is to introduce a shorter UL SPS interval, e.g. 1ms, as shown in Figure 1.

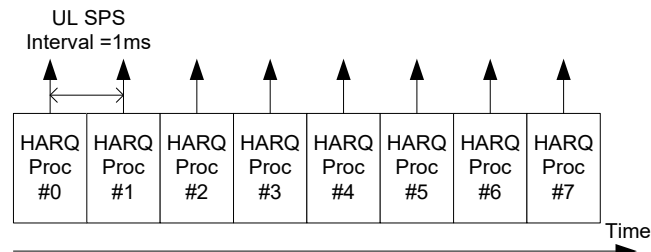


Figure 1: UL SPS with reduced (e.g. 1ms) Interval

With the reduced UL SPS interval, one problem is that the collision probability between new transmission and retransmission will increase. For example, if the reduced UL SPS interval is 1ms, then the first retransmission for transmission in subframe N will collide with the new transmission in subframe N+8, and this will negatively impact the transmission reliability by dropping the retransmission according to the current specification. Solutions need to be considered to address the collision problem.

2.2.2 Piggybacked UL Grant in DL packet

In some DL originated packet transmission scenarios, the interval between the DL packet and the subsequently UL packet is “predictable”, for example:

- After a DL TCP packet is sent, an UL TCP ACK is expected sometime later;
- After a DL RLC AMD PDU with Polling is sent, an UL RLC status report is expected sometime later;
- After an RRC Connection Reconfiguration message is sent, an RRC Connection Reconfiguration Complete message is expected sometime later.

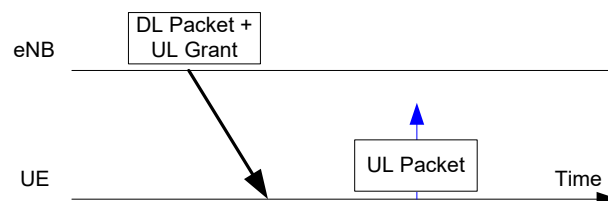


Figure 2: Piggybacked UL grant in DL packet

For the above scenarios, one possible way to reduce the PDCCH overhead is to piggyback the UL Grant in the DL packet (e.g. as one MAC CE, similar to the RAR), as shown in Figure 2. After the reception of the UL grant piggybacked in the DL packet, the UE will utilize the UL grant to perform the uplink transmission. The UL Grant could be kept valid within a range of subsequent TTIs.

2.3 Solutions to reduce the PUSCH overhead

2.3.1 Contention based uplink transmission

To alleviate the problem of unnecessary uplink PUSCH resource waste for the pre-scheduling solution, one possible way is to share the pre-scheduled PUSCH resources among several UEs, which called “Contention based uplink transmission”, as illustrated in Figure 3.

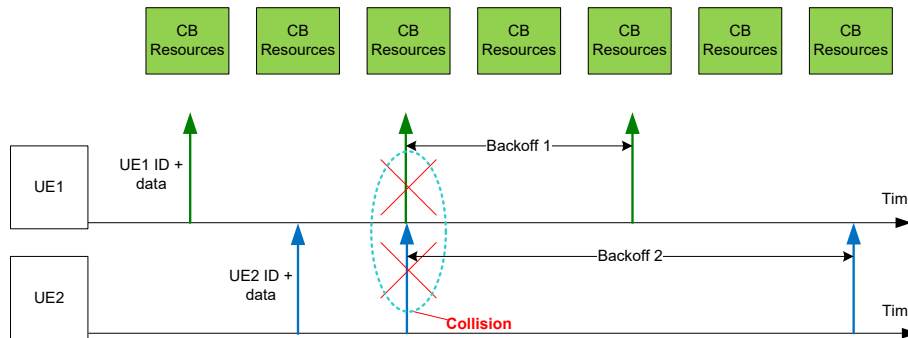


Figure 3: Contention based uplink transmission

When the UE has available uplink packet data, it will utilize the contention based PUSCH resource for the uplink transmission. Since the contention based PUSCH resource is shared among multiple UEs, the UE ID (e.g. C-RNTI) can be piggybacked in the uplink MAC PDU to enable the eNB to identify the exact UE that performed the uplink transmission. Alternatively, the eNB can distinguish different UEs that transmit on the same PUSCH resource by the DMRS sequence. After the successful decoding of the contention based uplink transmission (e.g. in case of no collision), the eNB may provide the ACK by PDCCH scrambled with UE's C-RNTI if the eNB uses the C-RNTI to distinguish different UEs, or by PHICH if the eNB uses the DMRS sequence to distinguish different UEs.

Since contention based uplink transmission is one mechanism to provide opportunistic uplink transmission, to simplify the system design, there is no need to perform the HARQ retransmission if the UE cannot receive the ACK after the contention based uplink transmission. Instead, the UE may retransmit the UL packet data following one of the following options:

- Option 1: The UE retransmits the UL packet data according to the ARQ feedback if AM RLC is used;
- Option 2: The UE back off randomly and then retransmit the UL packet data on another contention based PUSCH resource;
- Option 3: The UE requests the dedicated PUSCH resource to retransmit the UL packet data.

2.4 Solutions to increase the PUSCH utilization

2.4.1 Piggybacked control information on PUSCH

For the pre-scheduling solution, even though there is no valid data to transmit, the UE will still send something e.g. Padding and/or Padding BSR on the pre-scheduled uplink PUSCH resource. To further increase the PUSCH utilization for more useful information, one possible way is to piggyback some control information, e.g. CSI report, RLC status report and measurement report, into the UL MAC PDU, as shown in Figure 4.

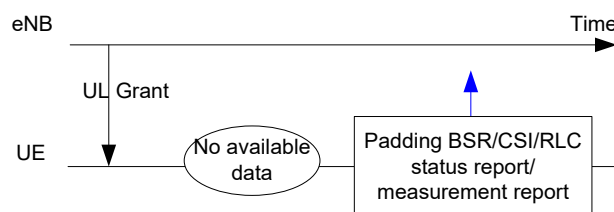


Figure 4: Piggybacked control information on PUSCH

2.5 Solutions to save UE transmission power and avoid uplink interference

2.5.1 Restrained uplink PUSCH transmission

To avoid the unnecessary UE battery consumption and uplink interference for the pre-scheduling solution, one possible way is to restrain the uplink PUSCH transmission on the pre-scheduled PUSCH resource in case there is no available UL packet data, as shown in Figure 5.

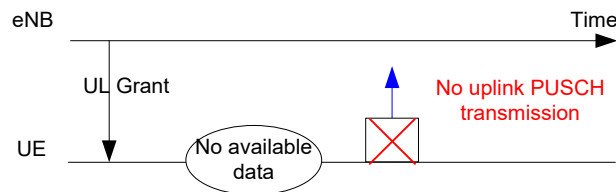


Figure 5: Restrained uplink PUSCH transmission

However, in case of no uplink transmission on the pre-scheduled PUSCH resource, the eNB cannot distinguish if it is because there is no available UL packet data, or because the eNB was failed to detect the uplink transmission due to poor radio condition. In this case, the eNB may schedule the UE to perform the uplink retransmission even if there is no available UL packet data. Solutions need to be considered to address such a problem.

3 Conclusion

In this contribution, we first analyzed the problems of the pre-scheduling solution, and we have the following observation:

Observation: The pre-scheduling solution with small period has the following problems:

- Significant PDCCH overhead
- Unnecessary uplink PUSCH resource waste
- Unnecessary uplink interference
- Unnecessary UE battery consumption

Then, we discussed possible solutions to reduce the uplink transmission latency for active UEs (i.e. synchronized UEs), and to address the problems of the pre-scheduling solution. The possible solutions are summarized as below:

- **Solutions to reduce the PDCCH overhead**
 - UL SPS with reduced interval
 - Piggybacked UL Grant in DL packet
- **Solutions to reduce the PUSCH overhead**
 - Contention based uplink transmission
- **Solutions to increase the PUSCH utilization**
 - Piggybacked control information on PUSCH
- **Solutions to save UE transmission power and avoid uplink interference**
 - Restrained uplink PUSCH transmission

We have the following proposal:

Proposal: Discuss the possible solutions in this contribution and capture them into TR 36.881.

4 References

- [1] RP-150465, New SI proposal Study on Latency reduction techniques for LTE; Ericsson, Huawei
- [2] R2-153375, Problems of the current LTE system on latency; Huawei, HiSilicon