

Source: Ericsson
Title: Uplink ACK/NACK timing for TDD
Agenda Item: 6.3.7
Document for: Discussion and Decision

1. Introduction

This contribution is a resubmission of R1-080367.

According to [1], for FDD, a UE shall upon detection of a PDSCH transmission in subframe n transmit an ACK/NACK in subframe $n+4$. For TDD operation, this is not possible since subframe $n+4$ not necessarily is an UL subframe. In the present contribution we discuss and propose the corresponding timing relation for TDD. More specifically, we propose to define the timing relations so that the maximum number of ACK/NAK in an UL subframe is minimized, this to preserve UL coverage.

2. Minimum processing delay

For an ordinary DL subframe, the terminal has to perform the same processing for both FDD and TDD and hence the same *minimum* delay between PDSCH transmission and ACK/NAK transmission is applicable. This holds also for data in the special field DwPTS which can be viewed as a punctured downlink subframe from a PDSCH perspective.

ACK/NACKs can, depending on whether the terminal has been granted uplink resources or not, be transmitted either on PUSCH or PUCCH. Since the same DL receiver processing has to be performed independently of UL, the same *minimum* delay between PDSCH transmission and ACK/NAK transmission applies independently of whether the ACK/NACK is transmitted on PUCCH or PUSCH. Further, to simplify the overall structure and avoid unnecessary flexibility, it is proposed that the same timing relation is used for ACK/NACK transmission on both PUCCH and PUSCH.

3. Simple rule – use first available UL subframe

Considering the processing delays, one would then propose that for TDD, the terminal would transmit the ACK/NACK in the first UL subframe at least four subframes later. The delay between PDSCH transmission and ACK/NACK then depends on the DL subframe number, as shown for the three possible UL:DL subframe allocations with 5ms periodicity shown in Figure 1.

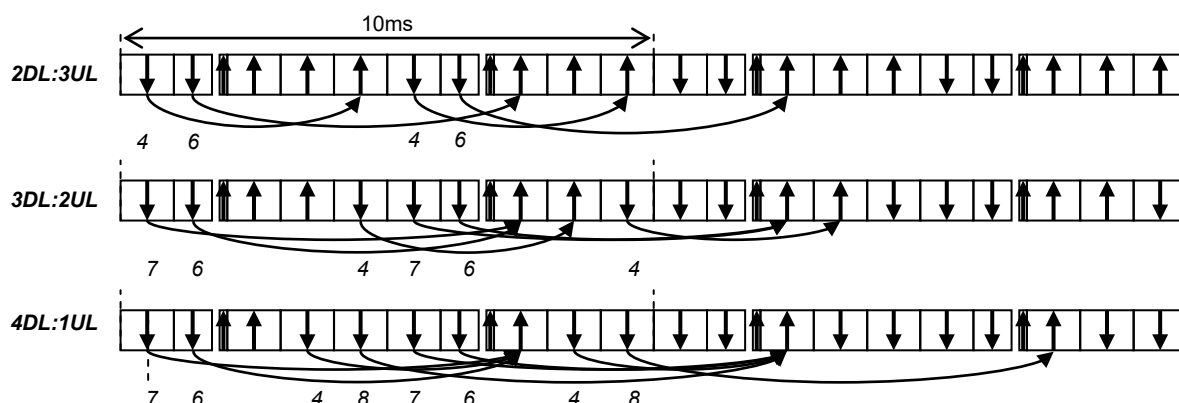


Figure 1 ACK/NACK is transmitted in first available UL subframe for three DL:UL allocations with 5ms periodicity.

For certain allocations, more specifically the allocations with 10ms periodicity, the maximum number of ACK/NACKs in each UL subframe, and hence performance, may be very different for different subframes. As an example, let us consider an allocation with 8 DL subframes (including DwPTS) and 2 UL subframes (excluding UpPTS) and a single switch point pair per 10ms. Using the simple rule to use the first available UL subframe subject to a certain processing delay would result in ACK/NACKs from seven (7) DL subframes in the first UL subframe and a single ACK/NACK from a single DL subframe in the second UL subframe. This is illustrated in Figure 2.

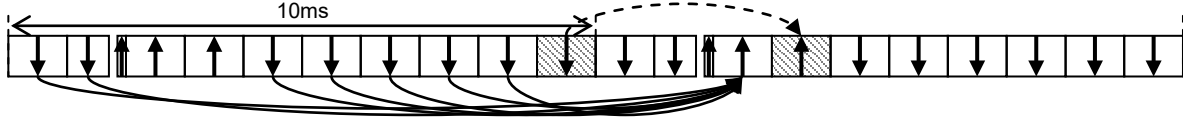


Figure 2 Example of ACK/NACK transmission in first available UL subframe after a certain processing delay (3ms minus round trip propagation delay)

4. Time domain spreading of ACK/NACKs

From an UL performance perspective, primarily coverage, we prefer to distribute the ACK/NACKs in time domain to minimize the maximum number of ACK/NACKs to be transmitted in an UL subframe. This would mean that the transmission of some of the ACK/NACKs are additionally delayed so that for the 8DL:2UL example considered previously, ACK/NACKs for at most four subframes are transmitted in each of UL subframe. This is illustrated in Figure 3.

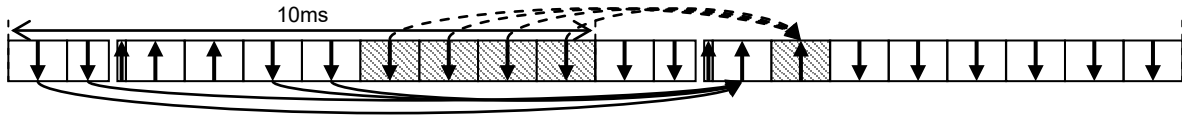


Figure 3 Example of ACK/NACK transmission where the ACK/NACKs are spread in time domain.

Further, for the allocations 7DL: 3UL, 8DL: 2UL and 9DL: 1UL and processing delay under consideration (3ms in eNodeB), we have also found that the maximum number of DL processes is not affected. Hence, when the maximum number of processes is used, the additional delay on the ACK/NAK has no impact on the DL round trip time either. Additionally, for allocations with 5ms periodicity, 2DL:3UL, 3DL:2UL and 4DL:1UL, there is no need to introduce any additional delay to balance the ACK/NAK transmission of different UL subframes, since the maximum number of ACK/NACKs per subframe can anyway not be reduced. In Figure 4, timing relations for time domain spreading are shown for three DL: UL allocations with 10ms periodicity.

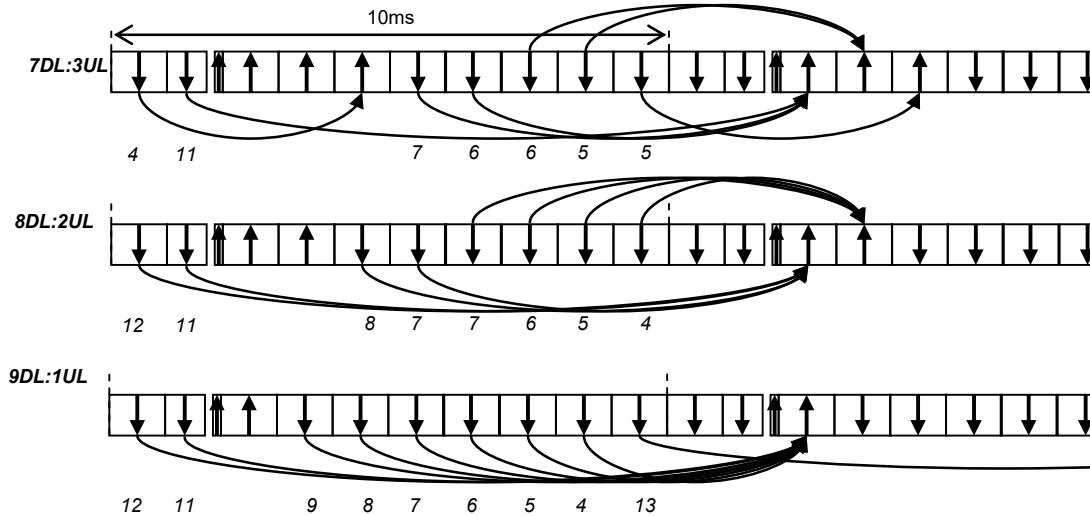


Figure 4 ACK/NAK delays are chosen to spread them in the time domain for three UL:DL allocations with 10ms periodicity.

In summary, UL coverage can be improved by spreading the ACK/NACKs in time domain for the allocations with 10ms periodicity. This will improve the coverage and for a given DL:UL allocation reduce the number of ACK/NACKs to be transmitted in a single UL subframe. Below in Table 1, the delays are presented for the in total six UL:DL allocations discussed above.

		DL subframe n									
		0	DwPTS	2	3	4	5	DwPTS	7	8	9
DL:UL allocation	2DL:3UL	4	6	-	-	-	4	6	-	-	-
	3DL:2UL	7	6	-	-	4	7	6	-	-	4
	4DL:1UL	7	6	-	4	8	7	6	-	4	8
	7DL:3UL	4	11	-	-	-	7	6	6	5	5
	8DL:2UL	12	11	-	-	8	7	7	6	5	4
	9DL:1UL	12	11	-	9	8	7	6	5	4	13

Table 1 Delays for ACK/NAK transmission. A UE shall upon detection of a PDSCH transmission in subframe n transmit an ACK/NAK in subframe $n+k$ where the k is given in the table.

4.1. Further time domain spreading

To further reduce the number of control signaling options, we note that the only allocation which requires the feedback of ACK/NACKs of three subframes is the 7DL:3UL allocation which transmits 3, 2 and 2 ACK/NACKs in the three UL subframes, respectively. By reducing the additional delay, of two subframes, one may transmit ACK/NACKs in the three UL subframes, respectively. Considering all UL:DL allocations, we note that 1, 2, 4 and 9 ACK/NACKs in an UL subframe need to be supported. However, since the main advantage of spreading the ACK/NACKs in the time domain is to improve coverage, this is not considered at the present point.

5. Conclusion

We noted that the UL ACK/NACK timing in [1] is not applicable for LTE TDD since UL transmission is not continuous. We propose that

- The same timing relation is used for ACK/NAK transmission on PUSCH and PUCCH
- The delay between PDSCH reception and ACK/NAK transmission is
 - a function on the subframe number,
 - chosen dependent on the allocation of subframes to UL and DL, and
 - chosen to reduce and balance the maximum number of ACK/NACKs transmitted in an UL subframe..

6. References

- [1] 3GPP TS 36.213 v.8.1.0 (2007-12)