

Source: Panasonic

Title: Signalling for flexible subframes and determination of their usage

Agenda Item: 6.2.3.2

Document for: Discussion and Decision

1 Introduction

The following agreements have been reached in RAN1#72bis regarding signalling mechanisms for eIMTA:

- No new TDD UL-DL configurations are introduced in the BCT (in WI on TDD eIMTA)
- A signalling mechanism explicitly or implicitly indicates TDD UL-DL reconfiguration by either
 - PHY signalling (not including PBCH/MIB signalling), or
 - MAC signalling
- PBCH/MIB signalling issue could be revisited if reliability issue of the above method becomes severe

In addition, several contributions have discussed the use of flexible subframes within a radio frame, where a flexible subframe is determined dynamically as being used for uplink or downlink.

In this contribution, we present some views and thoughts about flexible subframes and related signalling, as well as the determination of their usage.

2 Flexible Subframes and Related Signalling

Up To Release 11, seven static TDD UL/DL configurations are defined as given in Table 1.

Table 1: Uplink-downlink configurations up to Release 11.

Uplink-downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

The motivation to introduce flexible subframes is at least partly to better adapt to varying traffic needs. As discussed before, one preferred way of operating a backward-compatible cell is to use an uplink-heavy TDD configuration as indicated in SIB1, and selectively being able to replace one or more U subframes by D. In the broad sense, therefore a new subframe type F is introduced, which can be dynamically used as U or D.

Proposal 1: For a backward compatible operation, only those subframes indicated by SIB1 as U can be flexible subframes.

Looking at Table 1, we can assess the usable DL resources expressed as a ratio compared to a radio frame that consists solely of DL subframes (i.e. 1.0 is equivalent to 10 D subframes per radio frame). The equivalent downlink resources of a special subframe depend on the special subframe configuration; here we assume that DwPTS has a length of 19760 samples (special subframe configuration 1 and 6 using normal CP). Such a special subframe provides roughly 64% of the resources in a D subframe. Table 2 shows the equivalent DL resource ratio of the seven TDD configurations.

Table 2: Uplink-downlink configurations, DL resource ratio.

UL/DL configuration	DL resource ratio
0	0.328
1	0.528
2	0.728
3	0.664
4	0.764
5	0.864
6	0.428

Replacing one or more U subframes by flexible subframes increases this DL capacity. The practical limit is the resource ratio of UL/DL configuration 5.

One aspect for the UE implementation is that it is not possible to use one subframe for downlink and the subsequent subframe for uplink, since a gap is required to accommodate for timing advance and the RF switching reason. As a flexible subframe could be used for uplink or downlink, we think that flexible subframes should not be allowed where they may potentially cause a direct transition from downlink to uplink. Put into different words, to avoid the insertion of extra gaps and thereby reducing the capacity, a flexible subframe should only follow an uplink or special subframe, and it should only precede a downlink subframe.

Proposal 2: A subframe n can only be flexible if subframe n+1 is defined as D, and if subframe n-1 is defined as U or S.

In order to always be able to transmit HARQ-ACK for downlink transmissions, we think that at least one subframe per radio frame should be always available for uplink. This is easily fulfilled by defining that subframe 2 is always U, regardless of the UL/DL configuration or flexible/non-flexible subframe usage.

Proposal 3: Subframe 2 of each radio frame is always defined as U.

Combining Proposal 1 with Proposals 2 and 3, and the agreement from RAN1#72bis that no new configurations are defined, we find that flexible configurations (denoted by 'Fn' for clarity) based on the static configurations are possible as shown in Table 3.

Table 3: Flexible Uplink-downlink configurations.

Uplink-downlink configuration	Subframe number									
	0	1	2	3	4	5	6	7	8	9
F0	D	S	U	U	F	D	S	U	U	F
F1	D	S	U	F	D	D	S	U	F	D
F2	D	S	U	D	D	D	S	F	D	D
F3	D	S	U	U	F	D	D	D	D	D
F4	D	S	U	F	D	D	D	D	D	D
F5	D	S	U	D	D	D	D	D	D	D
F6	D	S	U	U	F	D	S	U	F	D

Obviously, the DL resource ratio of configuration 5 cannot be further increased when subframe 2 should be kept as U, therefore configuration F5 is equivalent to configuration 5 in all aspects.

Although this seems to add 'only' one or two flexible subframes, we note that the DL resource gain against the static TDD configurations is substantial and sufficient to accommodate easily to traffic changes, as shown in Table 4, with the same rationale as in Table 2.

Table 4: Increase of DL resource ratios by flexible subframes.

UL/DL configuration	Max increase of DL resources
F0 vs. 0	+61%
F1 vs. 1	+38%
F2 vs. 2	+14%
F3 vs. 3	+15%
F4 vs. 4	+13%
F6 vs. 6	+47%

The largest gains are to be observed for configurations 0, 1 and 6, which are also the most likely to be operated for backward compatibility reasons.

As we can observe from Table 4, the potential gains that can be reached by the configuration according to Table 3 are already substantial and should be sufficient to adapt to traffic variations.

In addition, it is possible to establish an unambiguous implicit relation between a static TDD configuration and a flexible TDD configuration, which obviates the need for an explicitly signalled secondary or reference higher-layer TDD configuration parameter, which would be used to determine flexible subframes as those where the SIB1 and the secondary TDD configuration show a different D/S/U usage.. We think that the benefit for introducing such a new higher layer configuration would need to be proven, taking into account that too many options and combinations put additional burden on the implementation and on testing same.

Proposal 4: No additional higher layer signal or parameter is introduced to indicate which subframe is a flexible subframe.

If the above DL resource ratio is not sufficient for the flexibility for the adaptation of the traffic, to increase flexible subframe further like following is also possible. The green coloured part is additional flexible subframe. This can increase the number of flexible subframes. As described in Proposal 2, a downlink subframe followed by an uplink subframe needs to handle timing advance and RF switching. To avoid such a loss of UL/DL capacity, two successive flexible subframes must be only "DD", "UD" or "UU".

Table 5: Additional Flexible Uplink-downlink configurations.

Uplink-downlink configuration	Subframe number									
	0	1	2	3	4	5	6	7	8	9
F0	D	S	U	F	F	D	S	U	F	F
F1	D	S	U	F	D	D	S	U	F	D
F2	D	S	U	D	D	D	S	F	D	D
F3	D	S	U	F	F	D	D	D	D	D
F4	D	S	U	F	D	D	D	D	D	D
F5	D	S	U	D	D	D	D	D	D	D
F6	D	S	U	F	F	D	S	U	F	D

Instead of introducing more flexible subframes requiring specification to avoid D-to-U transitions, an alternative to allow more dynamic traffic adaptation without incurring such problems would be to abandon the flexible subframe concept, and instead to determine the applicable UL/DL configuration from the existing set 0-6 e.g. by explicit PHY signalling radio frame by radio frame, in case it diverges from the configuration indicated by SIB1. In this way, the eNodeB has the flexibility to adapt the D/U ratio radio frame by radio frame as and only if required.

3 Determination of Flexible Subframe Usage

When using a flexible TDD configuration as in Table 3, it is further necessary to specify how the UE determines whether an F subframe should be treated as U or D dynamically. As Table 3 is constructed based on U subframes that are re-defined to F subframes, we think a sufficiently simple means is to make the usage of a flexible subframe depending on the presence of a scheduled PUSCH transmission in the flexible subframe, i.e. dependant on the presence of an UL grant assigning a PUSCH transmission in a flexible subframe, taking the DCI-to-PUSCH timing for the respective TDD configuration into account; currently this UL grant needs to be transmitted 4, 5, or 7 subframes prior to the respective subframe, depending on the subframe index and the TDD configuration. We think this timing relation should be kept to leave the UE sufficient time for detecting the UL grant and corresponding processing. While the

presence of a detected UL resource assignment determines that the corresponding flexible subframe is treated as U, the lack of a detected UL resource assignment should determine that the corresponding flexible subframe is treated as D.

Proposal 5: Detecting a DCI assigning an uplink transmission in a flexible subframe determines that the flexible subframe is used as U.

Proposal 6: Not detecting a DCI assigning an uplink transmission in a flexible subframe determines that the flexible subframe is used as D.

Proposal 7: The subframe n where the DCI containing an UL grant is detected for a flexible subframe $n+k$ is using the same timing as for detecting a DCI containing an UL grant for a non-flexible subframe $n+k$ in the same configuration.

If the UE detects that a flexible subframe is used as D, it should then proceed to detect PDCCH/EPDCCH in that flexible subframe as for any other D/S subframe. We don't identify any need to detect UL resource assignments or TPC in any flexible subframe used as D because all U subframe can be indicated by fixed D subframe. Therefore, the corresponding DCI formats in flexible subframe should not be detected to be safe against erroneous detections. Consequently, the UE should only detect DL resource assignments in flexible subframes used as D. Therefore, we don't see any issue on control channel transmission.

Proposal 8: In a flexible subframe that is used as D, the UE detects only DL resource assignments.

4 Concerns on Implicit Reconfiguration

Above method would be categorized as implicitly indicating the TDD UL-DL reconfiguration by PHY signalling. Some contribution describes the drawback of such schemes. Our views on these points are following.

➤ UE power consumption

When DRX/DTX is not configured and if no UL grant is received, the UE assumes DL behaviour for the flexible subframe. But even when processing such a DL reception, the maximum power consumption is less than in the FDD case or at most equal to UL/DL configuration 5. When DRX/DTX is configured, an explicit signalling method requires to wake-up in additional subframes in order to receive explicit signalling, otherwise explicit signalling is required to be sent every subframe, which is too excessive. We think the amount of the power consumption depends on how DRX/DTX is configured.

➤ False detection

The gravest new issues would be the false detection of an uplink grant for a flexible subframe where none is transmitted and the subsequent loss of a downlink transmission in the corresponding flexible subframe, and the case of falsely detecting a DL transmission in a flexible subframe even though none was transmitted. The first case is not more likely than any normal false uplink grant detection, and the second case is not more likely than any normal false downlink assignment detection. Therefore, we don't think it is critical problem, but it might be further studied to improve these aspects if the group intends to go this way. More important for the false detection is not to keep the states forever by the dynamic signalling. The mentioned implicit method can be designed to determine the behaviour individually for each flexible subframe, or at most to determine the flexible subframe usage within one radio frame. Therefore, the false detection error does not propagate beyond a 10 ms period.

➤ CSI measurement

CSI measurement in implicit method has been mentioned as a problem. One issue is the handling of periodic CSI. Periodic CSI can be configured to be obtained only for fixed subframes, and it is also possible to rely on aperiodic CSI reporting.

The second issue is CSI measurements in flexible subframe. IMR/SMR CSI-RS could be transmitted for TM 10 in flexible subframes. These can be aperiodic CSI-RS resource. Transmission Modes using CRS for CSI measurements leave flexibility on where interference is measured. Therefore, without new restrictions, CSI reporting from UE may not represent the interference situation in flexible subframes accurately. Instead, to focus on TM 10 could reduce the complexity. In addition, TM 10 is DMRS based. DMRS based Transmission Modes have more flexibility on DL power control, which is quite essential for interference mitigation for eIMTA.

5 Conclusion

This contribution shows our views on how flexible subframes could be realised in context of eIMTA. Several proposals are listed below to simplify the design while offering sufficient flexibility to adapt to traffic needs.

Proposal 1: For a backward compatible operation, only those subframes indicated by SIB1 as U can be flexible subframes.

Proposal 2: A subframe n can only be flexible if subframe $n+1$ is defined as D, and if subframe $n-1$ is defined as U or S.

Proposal 3: Subframe 2 of each radio frame is always defined as U.

Proposal 4: No additional higher layer signal or parameter is introduced to indicate which subframe is a flexible subframe.

Proposal 5: Detecting a DCI assigning an uplink transmission in a flexible subframe determines that the flexible subframe is used as U.

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Proposal 8: In a flexible subframe that is used as D, the UE detects only DL resource assignments.