Proposed A-MAP Relevance and HARQ Timing for the IEEE 802.16m Amendment (Design Principles and Key Features)

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Venue:

Category: AWD-DG comments / Area: HARQ Protocol DG
"Comments on the Proposed Text of HARQ Protocol DG"

Base Contribution:

None

Purpose:

To be discussed and adopted by HARQ Protocol DG and TGm for the 802.16m Amendment

Proposed A-MAP Relevance and HARQ Timing for the IEEE 802.16m AWD
(Design Principles and Key Features)

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About this Contribution

- Goal and scope of this contribution
  - Introduce Design requirements for HARQ timing
  - Propose HARQ timing structure (in mathematical formula)
  - Show Benefits of the proposed HARQ timing
  - Present HARQ timings for various configurations in Appendix

- The proposed text for inclusion into the IEEE 802.16m AWD is shown in another contribution IEEE C802.16m-09/1130

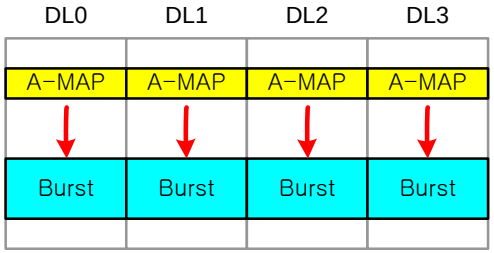
HARQ Timings

- HARQ protocols specified in the 16m SDD
  - Asynchronous HARQ for DL
  - Synchronous HARQ for UL

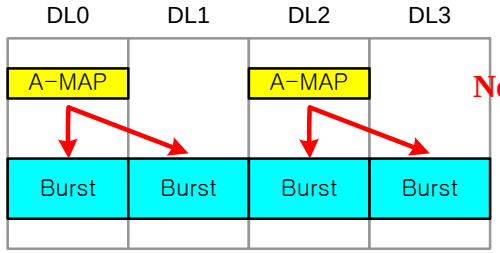
- Open issue: the detailed timing of HARQ operation
  - HARQ Feedback Delay
    - Both synchronous and asynchronous HARQ benefit from a predefined HARQ feedback delay
  - HARQ Retransmission Time
    - Synchronous HARQ in UL requires a predefined HARQ ReTx interval
    - The predefined HARQ ReTx interval is of benefit to power saving even in DL with asynchronous HARQ

A-MAP Relevance

- DL A-MAP Relevance
  - A-MAP Tx period = 1



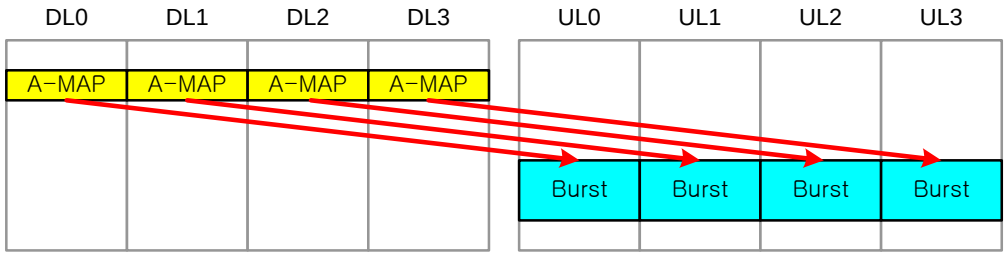
A-MAP Tx period = 2



Need an explicit indication

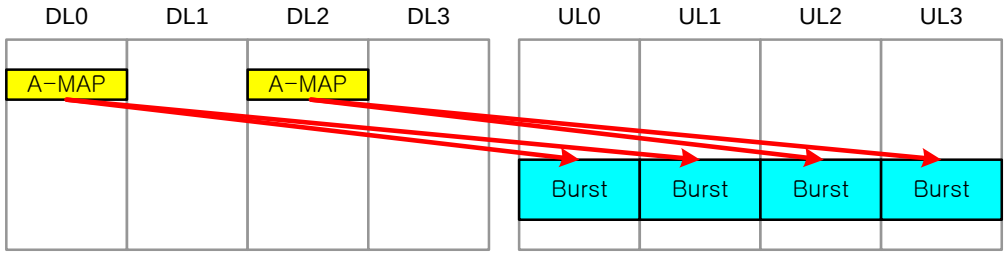
- UL A-MAP Relevance
  - A-MAP Tx period = 1

No need of an explicit indication. Just need a mapping rule.



  - A-MAP Tx period = 2

Need both an explicit indication and a mapping rule.



- In design of HARQ timing, A-MAP relevance shall be considered together.

Design Requirements

HARQ timing should …

① Represented by Mathematical formula for various configurations

- FDD and TDD (3:5, 4:4, 5:3, 6:2)
- 5/10/20MHz, 8.75MHz, 7MHz BWs (8, 7, 6 subframes per frame)
- Legacy support
- A-MAP Tx period = 1 or 2
- Long TTI transmission

② Maximize MS power saving and Efficiently support CLC (Co-Located coexistence)

- Provide a periodic HARQ timing for both feedback and Re-Tx
- Provide the synchronized DL and UL HARQ operations

③ Provide uniformly-distributed HARQ feedback timings

④ Support BS/MS with various capabilities in an efficient way

- Tx/Rx processing times of 2 subframes and 3 subframes

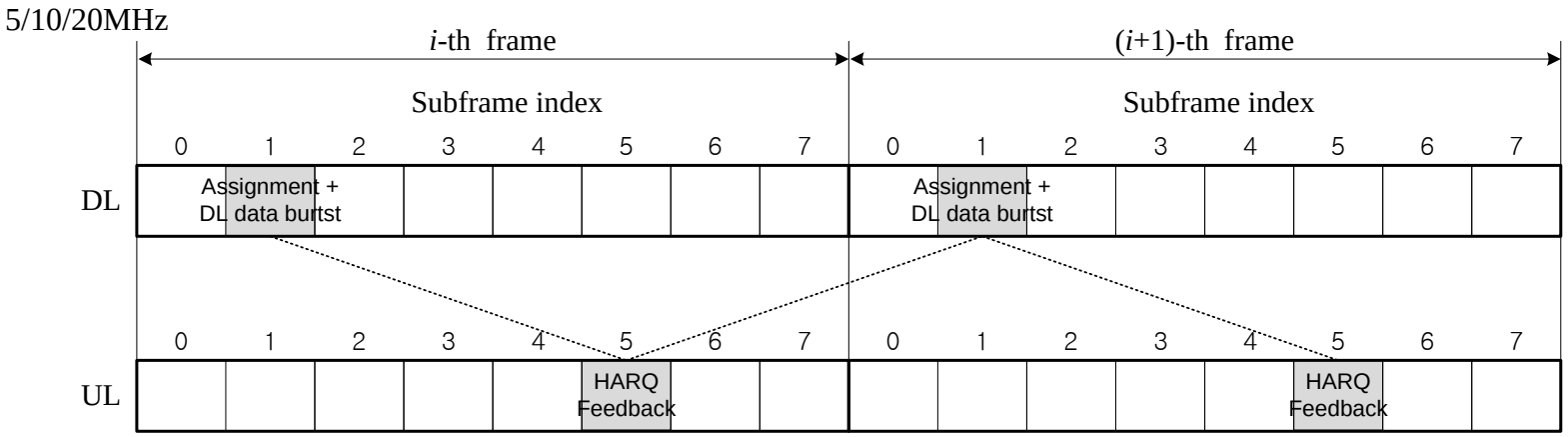
⑤ Be aligned with A-MAP relevance (particularly, in UL)

Tx/Rx Processing Time

- One of key considerations in design of MAP relevance and HARQ timing
  - ① Rx processing time at MS includes …
    - DL A-MAP decoding, Data burst decoding, ACK/NACK encoding
  - ② Tx processing time at MS includes …
    - UL A-MAP or ACK/NACK decoding, Data burst encoding
  - ③ Rx processing time at BS includes …
    - Data burst decoding, Scheduling, ACK/NACK or UL A-MAP encoding
  - ④ Tx processing time at BS includes …
    - ACK/NCACK decoding, Scheduling, DL A-MAP encoding, Data burst encoding

- The processing time in 16m: *2 subframes, 3 subframes*
  - Reasonable assumption, considering the implementation in near future and competitiveness with other standards
    - Note: 3 subframes in LTE, 2 subframes and 3 subframes in UMB

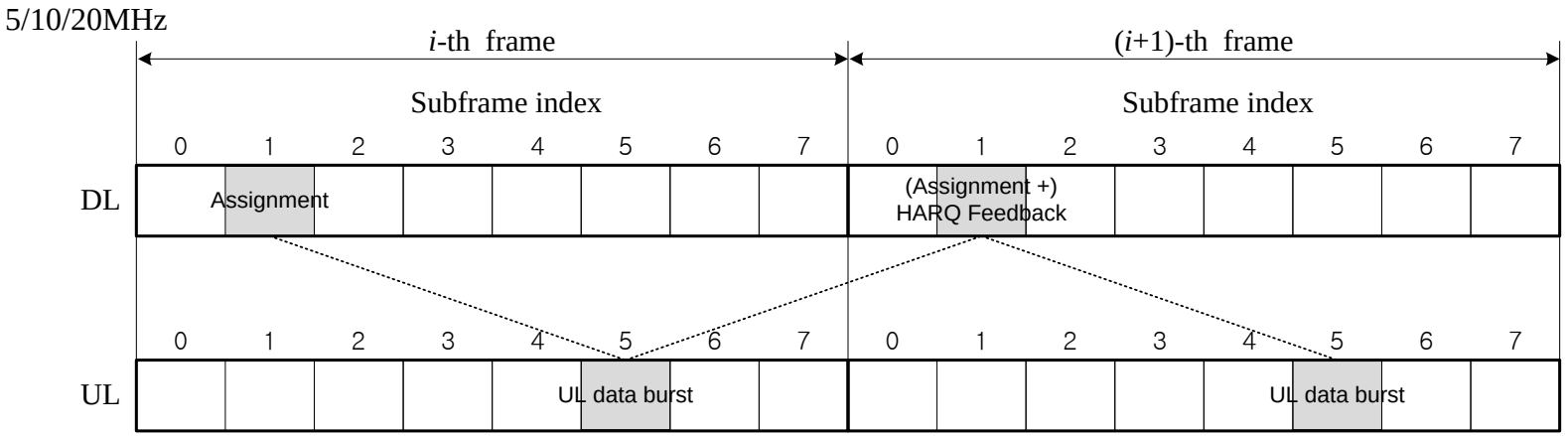
HARQ Timing in FDD DL



Content	Subframe index	Frame index
Basic Assignment A-MAP IE Tx in DL	l	i
HARQ Subpacket Tx in DL	$m = l$ or $l + N_{A-MAP} - 1$	i
HARQ feedback in UL	n = ceil(m+F/2) mod F	j = (i+floor(ceil(m+F/2)/F)+z) mod 4

- $N_{A\text{-}MAP}$: A-MAP transmission period
- F : num of subframe / frame (8 for 5/10/20MHz, 7 for 8.75MHz, 6 for 7MHz)
- z : DL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 14)

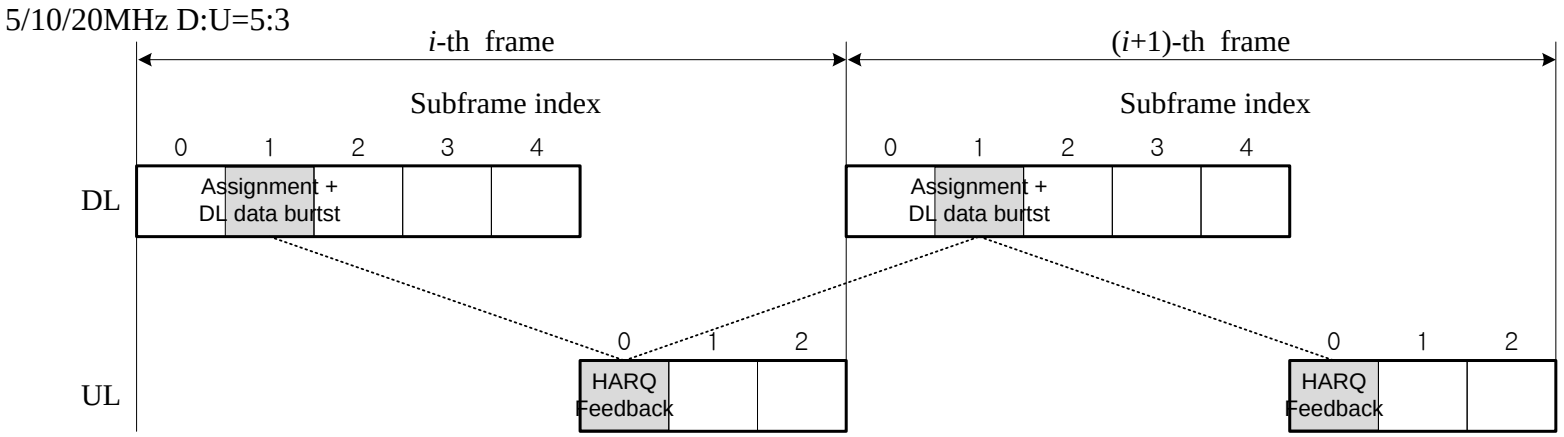
HARQ Timing in FDD UL



Content	Subframe index	Frame index
Basic Assignment A-MAP IE Tx in DL	l	i
HARQ Subpacket Tx in UL	$m = n$ or $n + N_{A-MAP} - 1$ where $n = \text{ceil}(l+F/2) \bmod F$	$j = (i+\text{floor}(\text{ceil}(l+F/2)/F)+v) \bmod 4$
HARQ feedback in DL	l	$k = (j+\text{floor}((m+F/2)/F)+w) \bmod 4$
HARQ Subpacket Re-Tx in UL	m	$p = (k+\text{floor}(\text{ceil}(l+F/2)/F)+v) \bmod 4$

- N_{A-MAP} : A-MAP transmission period
- F : num of subframe / frame (8 for 5/10/20MHz, 7 for 8.75MHz, 6 for 7MHz)
- v : UL HARQ Tx offset - 0 for fast Tx timing, 1 for slow Tx timing (see the slide 15)
- w : UL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 15)

HARQ Timing in TDD DL



Content	Subframe index	Frame index
Basic Assignment A-MAP IE Tx in DL	l	i
HARQ Subpacket Tx in DL	$m = l$ or $l + N_{A-MAP} - 1$	i
HARQ feedback in UL	For $D > U$, $n = \begin{cases} 0, & \text{for } 0 \le m < K \\ m - K, & \text{for } K \le m < U + K \\ U - 1, & \text{for } U + K \le m < D \end{cases}$ For $D \le U$, $n = m - K$	$j = (i+z) \bmod 4$

- $N_{A\text{-}MAP}$: A-MAP transmission period
- If $D+U$ is odd and $D < U/N_{A\text{-}MAP}$, $K = \text{ceil}((D-U)/2)$ for $D \ge U$, and $K = -\text{ceil}((U-D)/2)$ for $D < U$. Otherwise, $K = \text{floor}((D-U)/2)$ for $D \ge U$, and $K = -\text{floor}((U-D)/2)$ for $D < U$.
- z : DL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 14)

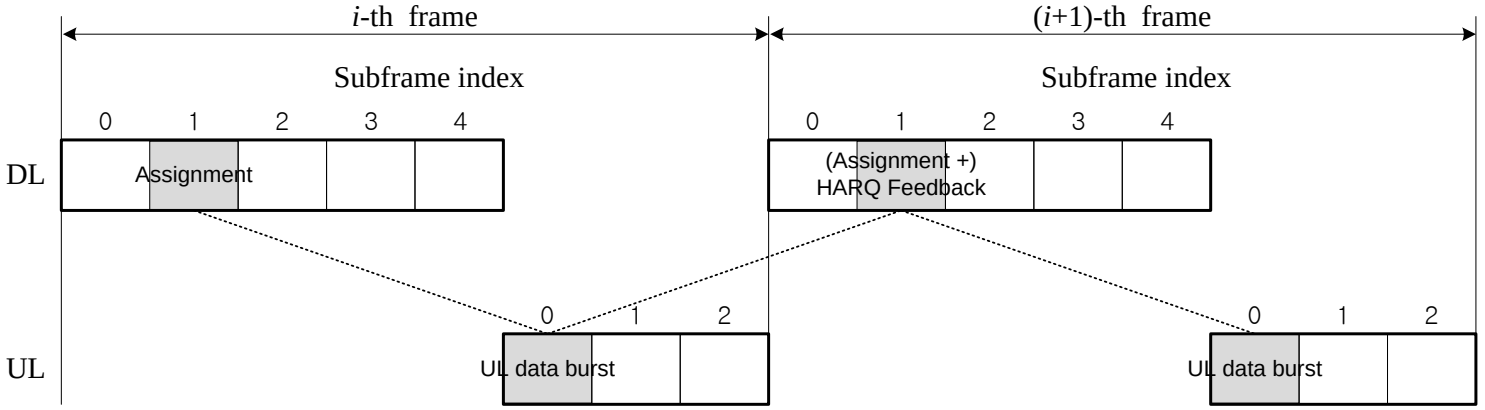
HARQ Timing in TDD UL (1/2)

Content	Subframe index	Frame index
Basic Assignment A-MAP IE Tx in DL	l	i
HARQ Subpacket Tx in UL	For ceil(D/ $N_{A\text{-}MAP}$) $\geq U$, $m = \begin{cases} 0, & \text{for } 0 \leq l < K \\ l-K, & \text{for } K \leq l < U+K \\ U-1, & \text{for } U+K \leq l < D \end{cases}$	$j = (i+v) \bmod 4$
	For 1< ceil(D/ $N_{A\text{-}MAP}$) <U, $m = \begin{cases} 0,\cdots,\text{or}\, l-K+N_{A-MAP}-1, & \text{for } l=0 \\ l-K \text{ or } l-K+N_{A-MAP}-1 & \text{for } 0<l<l_{\max} \\ l-K, l-K+1,\cdots,\text{or}\, U-1, & \text{for } l=l_{\max} \end{cases}$ where $l_{max} = N_{A\text{-}MAP}(\text{ceil}(D/N_{A\text{-}MAP})-1)$	
	For ceil(D/ $N_{A\text{-}MAP}$) =1, $m = 0,1,\cdots,\text{or}\, U-1$, for $l=0$	
HARQ feedback in DL	l	$k = (j+1+w) \bmod 4$
HARQ Subpacket Re-Tx in UL	m	$p = (k+v) \bmod 4$

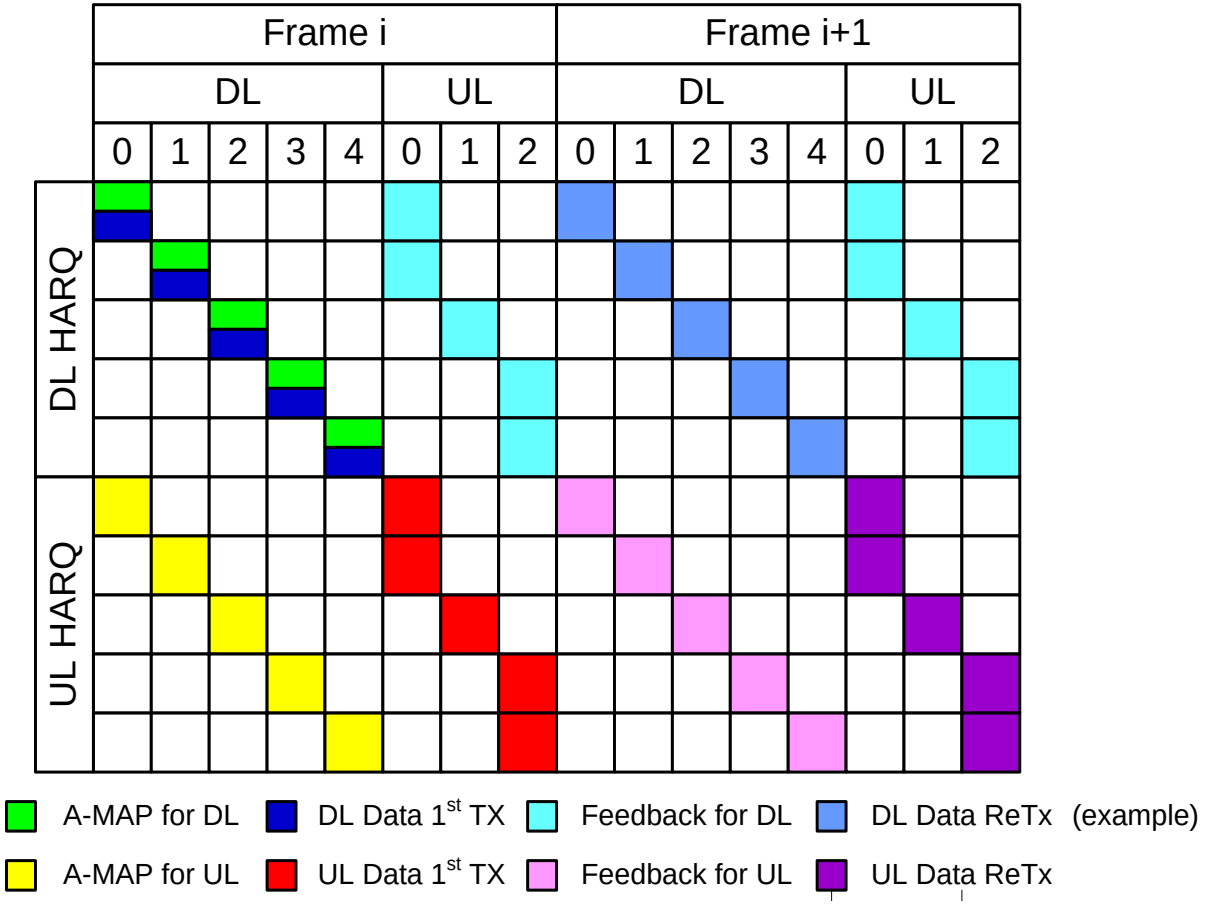
- $N_{A\text{-}MAP}$: A-MAP transmission period,
- If $D+U$ is odd and $D < U/N_{A\text{-}MAP}$, K = ceil((D-U)/2) for $D \geq U$, and K = –ceil((U-D)/2) for $D < U$. Otherwise, K = floor((D-U)/2) for $D \geq U$, and K = –floor((U-D)/2) for $D < U$.
- v : UL HARQ Tx offset - 0 for fast Tx timing, 1 for slow Tx timing (see the slide 15)
- w : UL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 15)

HARQ Timing in TDD UL (2/2)

5/10/20MHz D:U=5:3



HARQ Timing Illustration – TDD 5:3

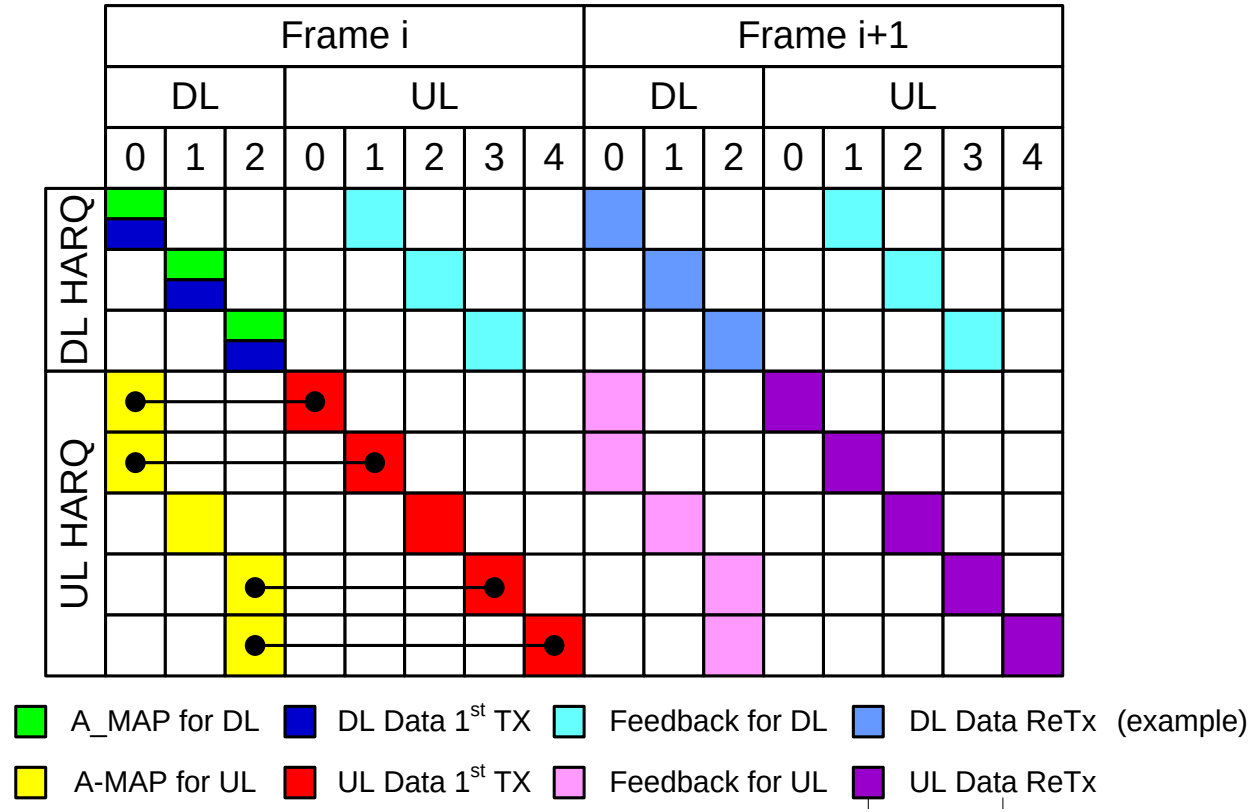


- The timing above provides a time gap of at least 2 subframes for Tx/Rx processing
- If a longer time gap (i.e. 3 subframes) should be secured,

  DL: a slow interlace is applied to subframe DL4 (see the slide after next)

  UL: Tx of UL A-MAP is limited to subframe DL1, DL2, and DL3.

HARQ Timing Illustration – TDD 3:5



- Both A-MAPs for UL0 and UL1 are transmitted in the same DL subframe (DL0)
- So, UL A-MAP IE shall include an indication of the assigned UL subframe

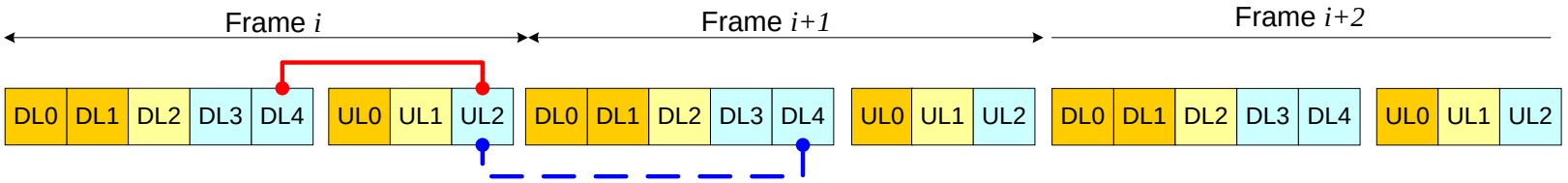
Two HARQ Timing Options (DL)

- DL feedback timing

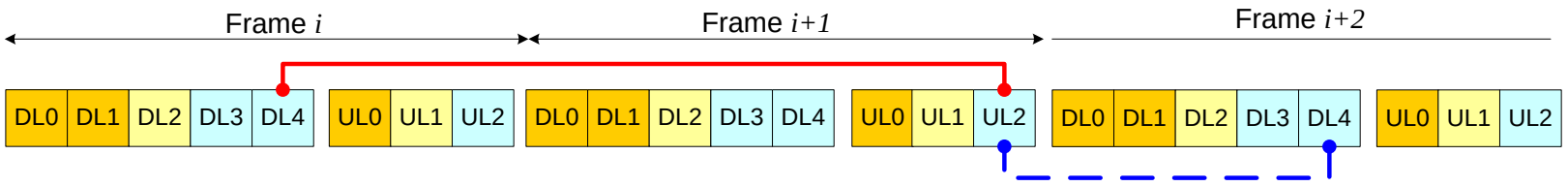
  ① Fast feedback (in the same frame) : z = 0

  ② Slow feedback (in the next frame) : z = 1

- Example – the last DL subframe in 5:3 TDD
  - If Rx processing time at MS = 2 subframe, the fast feedback (z = 0) is applied



  - Else (Rx processing time = 3 subframe), the slow feedback (z = 1) is applied

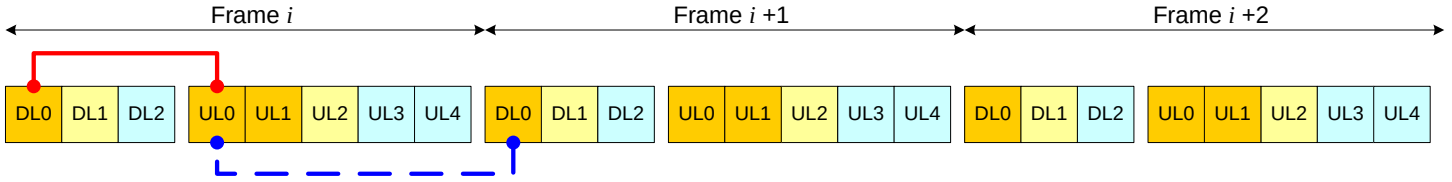


Two HARQ Timing Options (UL)

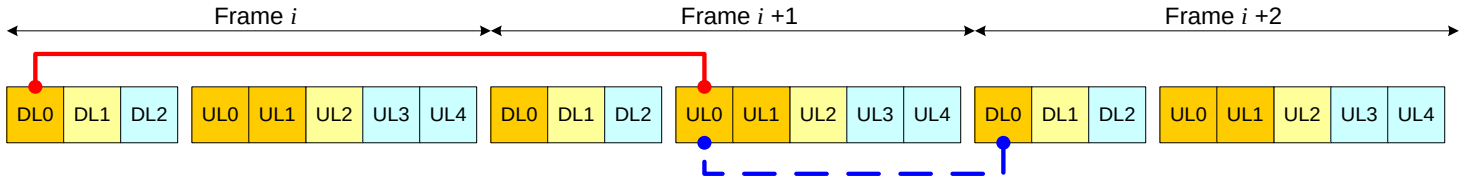
- UL data Tx timing (UL A-MAP relevance & ReTx timing)

  ① Fast transmission : v = 0, ② Slow transmission : v = 1

  - Example – the first UL subframe in 3:5 TDD
    - If Rx processing time at MS = 2 subframe, the fast transmission (v = 0) is applied



    - Else (Rx processing time = 3 subframe), the slow transmission (v = 1) is applied



- UL feedback timing

  ① Fast feedback : w = 0, ② Slow feedback : w = 1

  - Same as downlink

Timings for Various D/U ratios

Tx/Rx processing = 2 subframes

D:U = 3:5	DL			UL				
	0	1	2	0	1	2	3	4
DL HARQ	F	F	F		F	F	F	
UL HARQ	F	F	F	F	F	F	F	F

D:U = 4:4	DL				UL			
	0	1	2	3	0	1	2	3
DL HARQ	F	F	F	F	F	F	F	F
UL HARQ	F	F	F	F	F	F	F	F

D:U = 5:3	DL					UL		
	0	1	2	3	4	0	1	2
DL HARQ	F	F	F	F	F	F	F	F
UL HARQ	F	F	F	F	F	F	F	F

D:U = 6:2	DL						UL	
	0	1	2	3	4	5	0	1
DL HARQ	F	F	F	F	F	S	F	F/F/S
UL HARQ		F	F	F	F		F	F

Tx/Rx processing = 3 subframes

D:U = 3:5	DL			UL				
	0	1	2	0	1	2	3	4
DL HARQ	F	F	F		F	F	F	
UL HARQ	S/F	F	F/S	S	F	F	F	S

D:U = 4:4	DL				UL			
	0	1	2	3	0	1	2	3
DL HARQ	F	F	F	F	F	F	F	F
UL HARQ	F	F	F	F	F	F	F	F

D:U = 5:3	DL					UL		
	0	1	2	3	4	0	1	2
DL HARQ	F	F	F	F	S	F	F	F/S
UL HARQ		F	F	F		F	F	F

D:U = 6:2	DL						UL	
	0	1	2	3	4	5	0	1
DL HARQ	F	F	F	F	S	S	F	F/S/S
UL HARQ			F	F			F	F

DL HARQ

F: fast feedback
(ACK in the same frame)
S: slow feedback
(ACK in the next frame)

UL HARQ

F: fast interlace
(5ms Re-Tx interal)
S: slow interlace
(10ms Re-Tx interal)

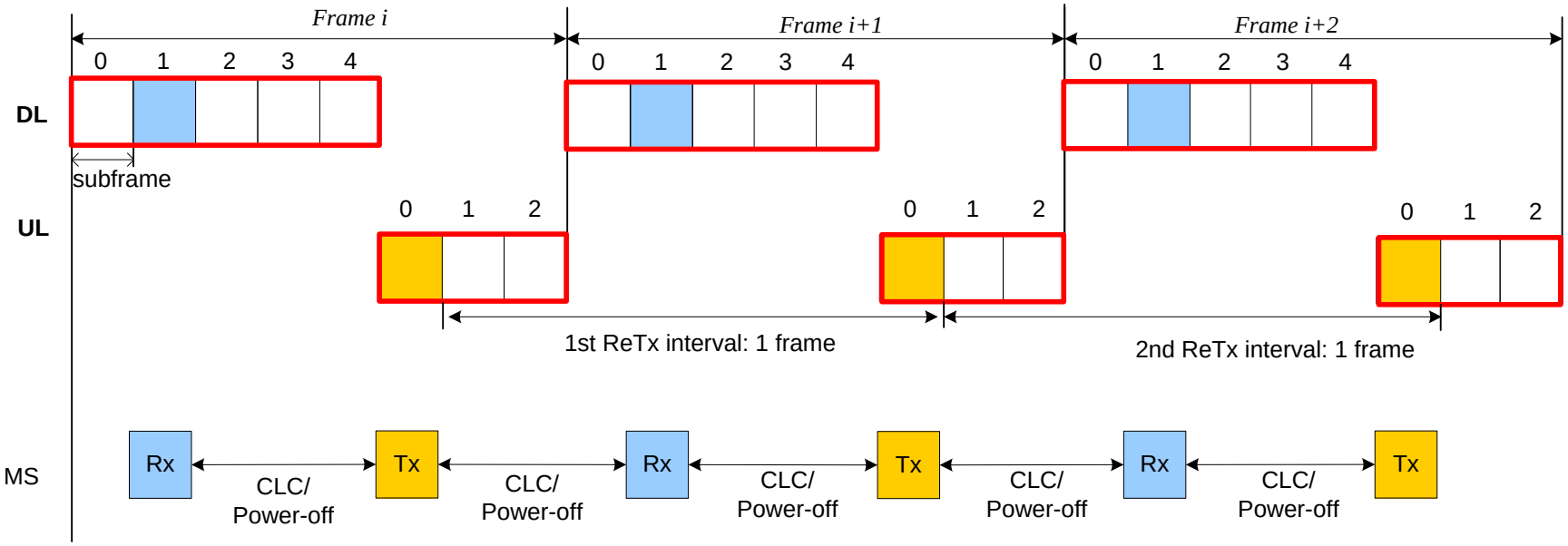
Features/Benefits of the Proposal

The proposed HARQ timing represented in the mathematical formula …

- Can be applied to all needed scenarios in 802.16m:
  - FDD, TDD (3:5, 4:4, 5:3, 6:2)
  - 5/10/20MHz (8 subframes/frame), 8.75MHz (7 subframes/frame), 7MHz (6 subframes/frame)
  - Frame Structure of Legacy support
  - A-MAP Tx period = 1 or 2
  - Long TTI transmission
- Maximize the efficiency of MS power saving and CLC
  - Periodic HARQ timing for both feedback and re-transmission
  - Synchronize DL and UL active cycles
- Balance the load of UL control signaling among subframes
  - By providing Uniformly-distributed HARQ feedbacks
- Very flexible but efficient to support the Tx/Rx processing times of 2 subframes and 3 subframes
- Be aligned with A-MAP relevance in UL
  - The same interval for “from A-MAP to Data Tx” and “from Feedback to Data Re-Tx”

Periodic HARQ Timing

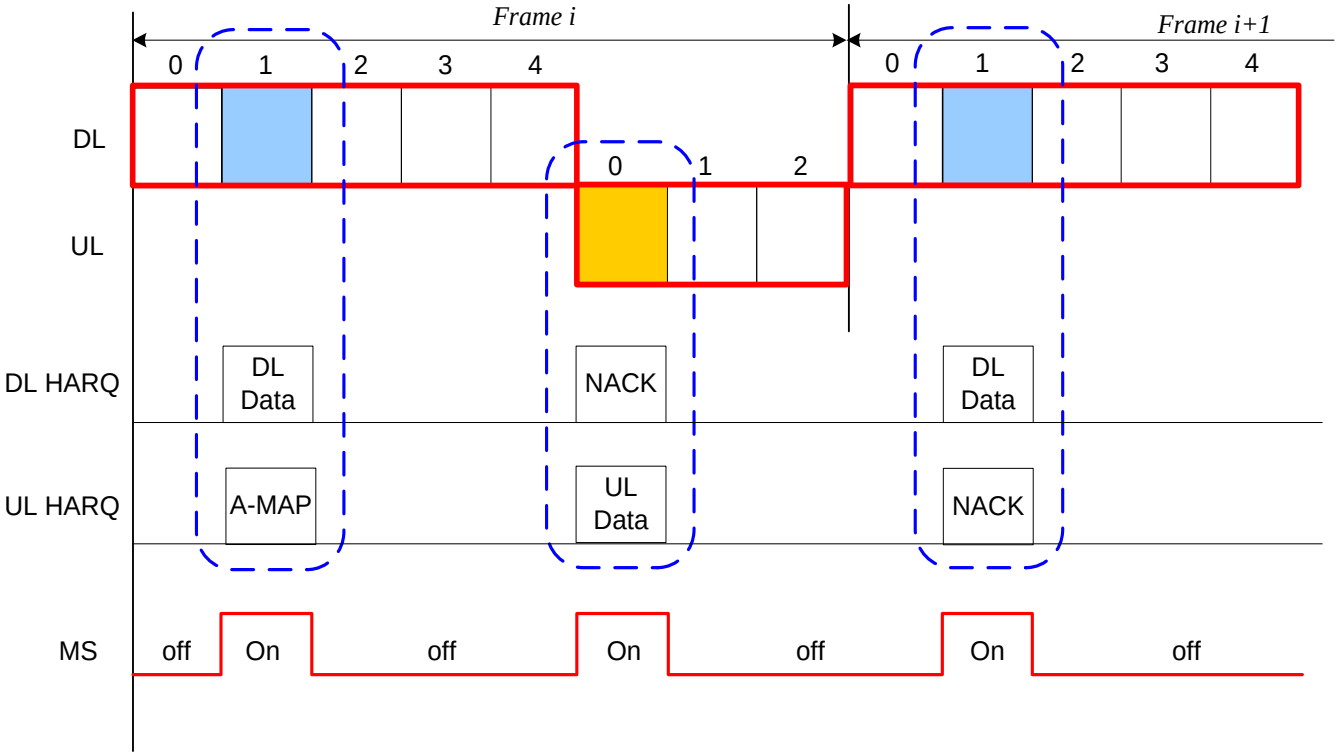
- A periodic Rx/Tx (duty cycle) is easily utilized for …
  - **Power Saving and CLC support**



Synchronize DL and UL Active Cycles

- Maximize Power Saving at MS
  - Same association of subframe for DL and UL HARQ operations

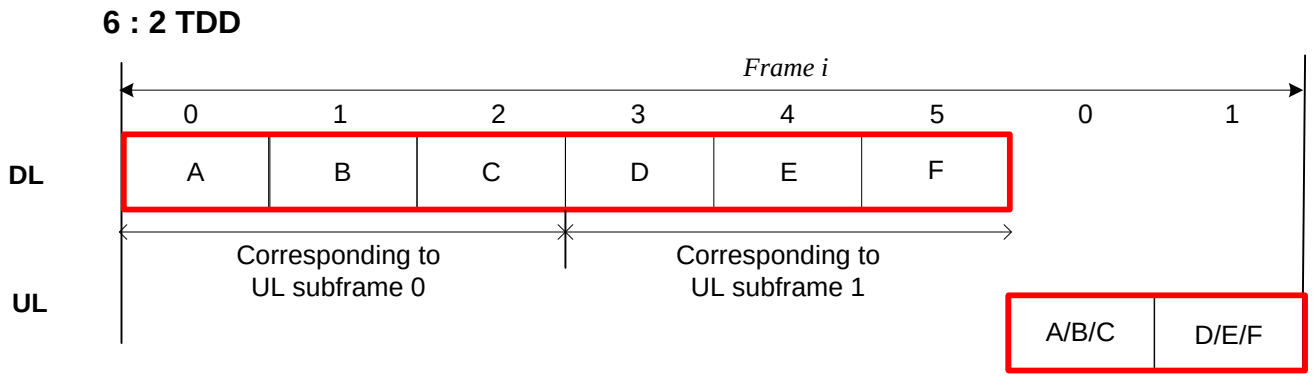
    ⇒ Synchronize DL and UL active cycles

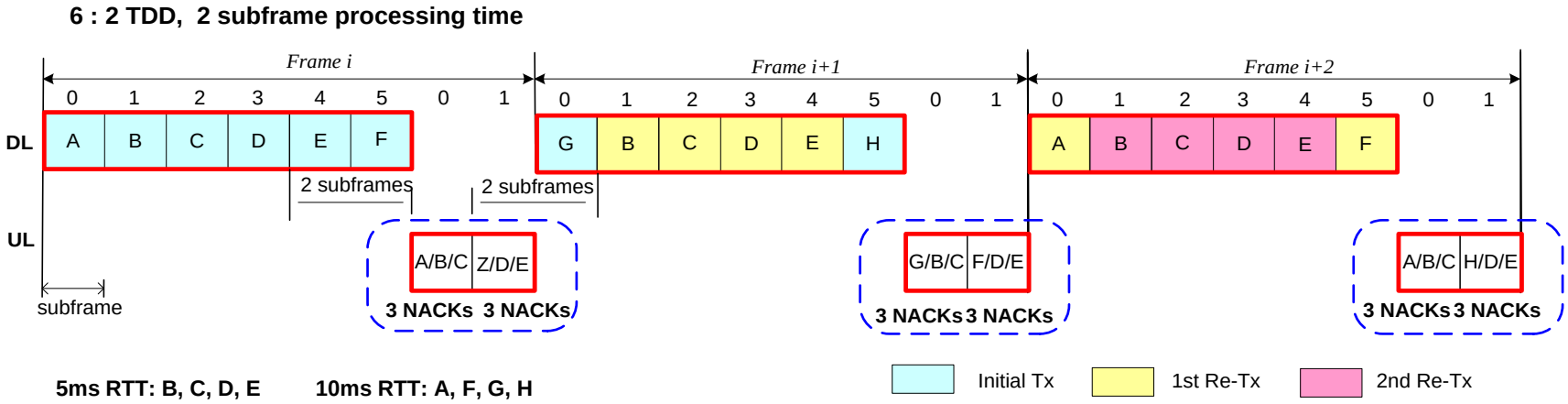


Note: MS is active only in DL subframe #1 and UL subframe #0; 1/4 activity

Uniformly-Distributed Feedbacks

- Each subframe has the same/similar number of associated subframes
  - Avoid the case when a number of HARQ feedbacks flow into a specific subframe





Appendix: HARQ timing illustration for …

1) **Legacy Support**

2) **8.75MHz, 7MHz Frames**

3) **A-MAP Tx period = 2**

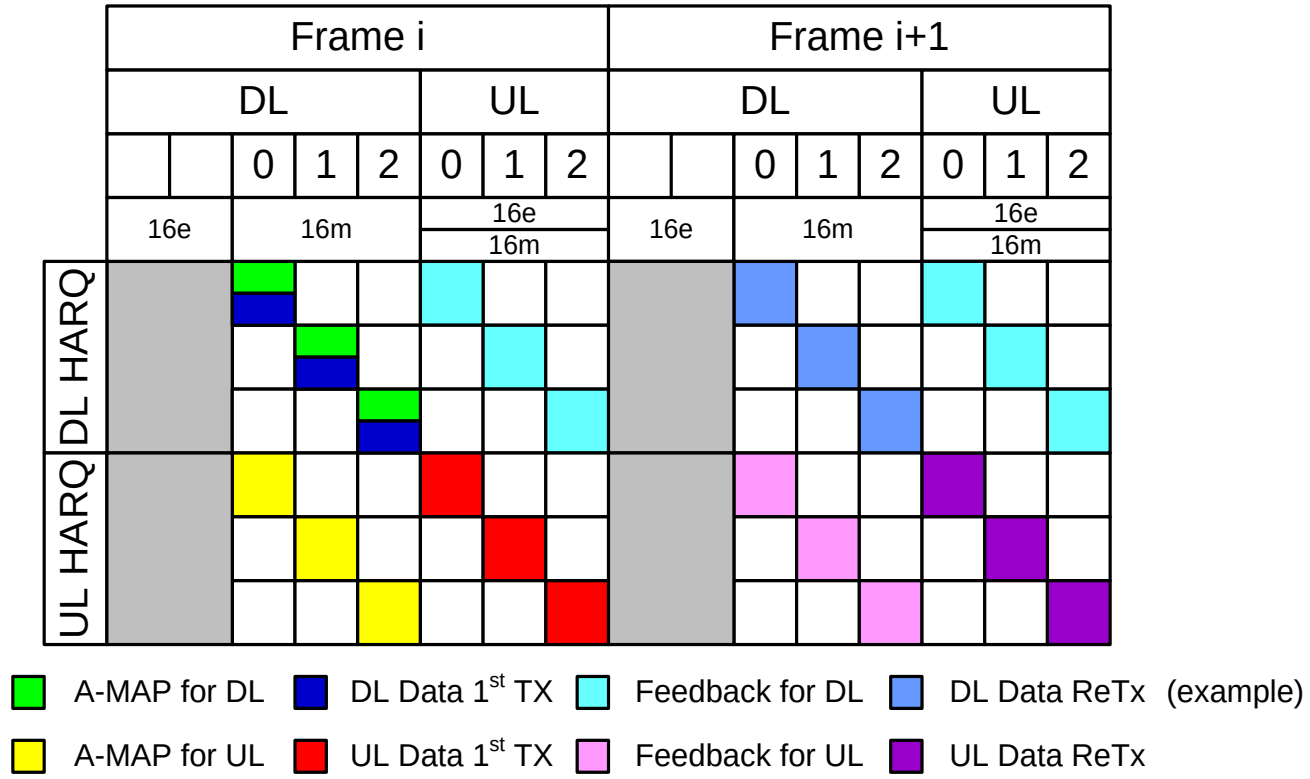
4) **Long TTI transmission**

5) **Relay Support**

Legacy Support – TDD 5:3 (1/2)

- 16e:16m = 2:3 (UL FDM)

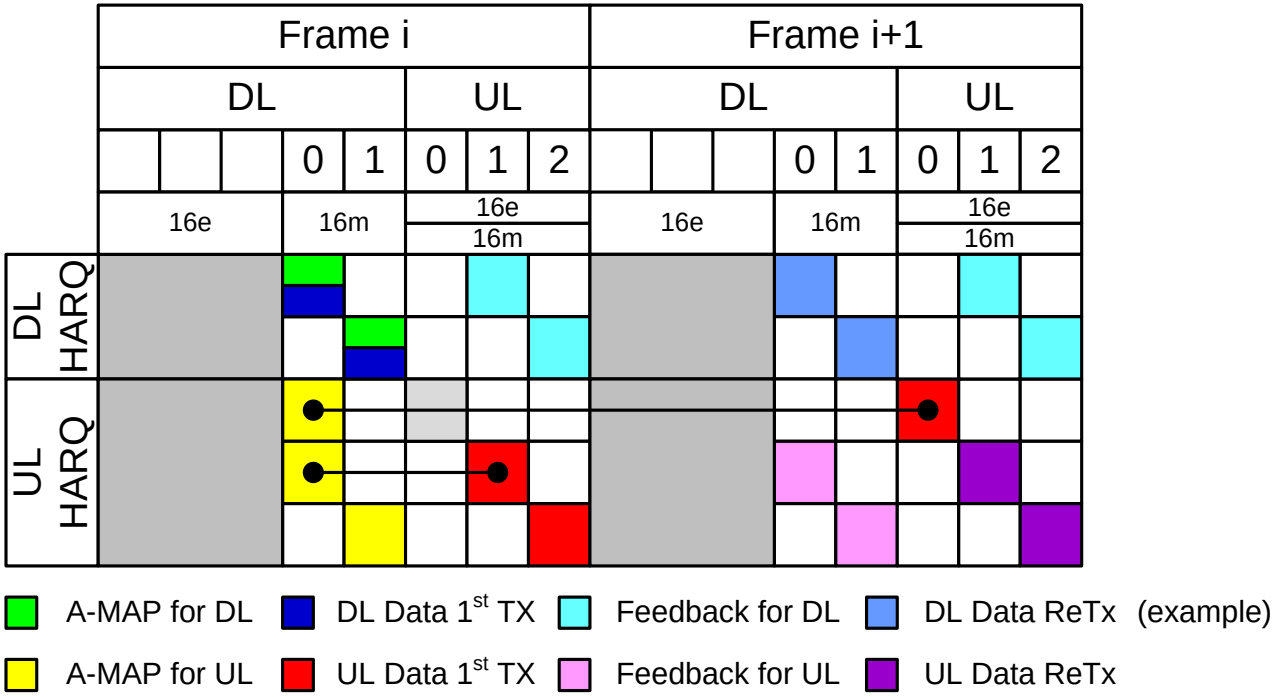
  ⇒ D:U = 3:3 at 16m (the same equation applied)



Legacy Support – TDD 5:3 (2/2)

- 16e:16m = 3:2 (UL FDM)

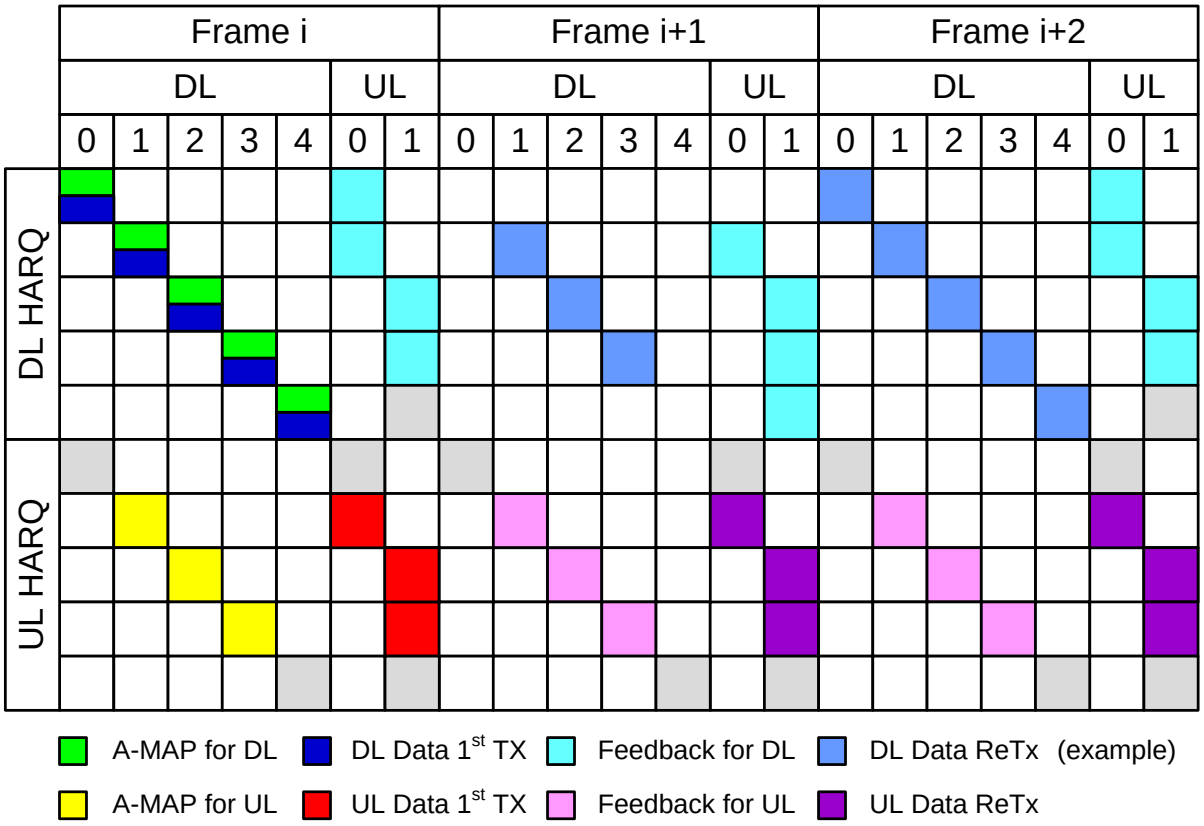
  ⇒ D:U = 2:3 at 16m (the same equation applied)



- Both A-MAPs for UL0 and UL1 are transmitted in the same DL subframe (DL0)
- So, UL A-MAP IE shall include an indication of the assigned UL subframe

8.75MHz Frame Structure (TDD 5:2)

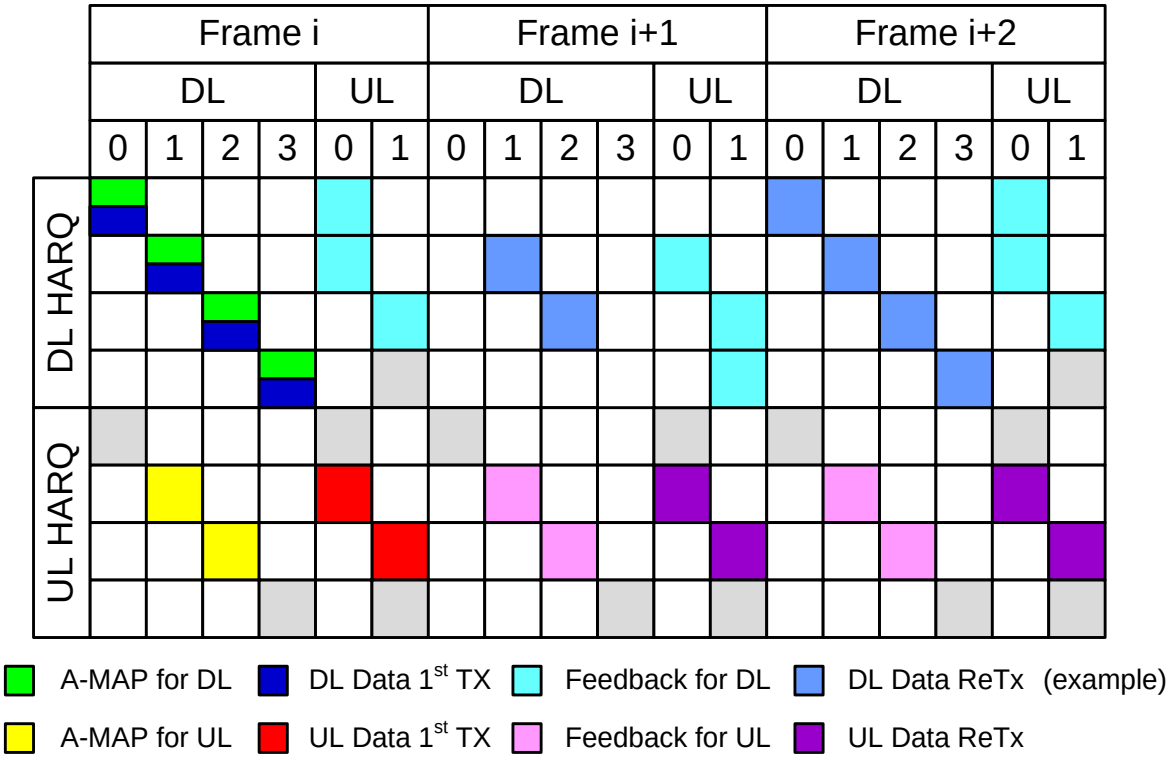
- The same equation applied



- The timing above provides a time gap of at least 2 subframes for Tx/Rx processing
- The gray-filled square indicates the expected timing but no transmission due to a too short Tx/Rx interval (1 subframe)
- If a longer time gap (3 subframes) should be secured, a slow interlace is applied

7MHz Frame Structure (TDD 4:2)

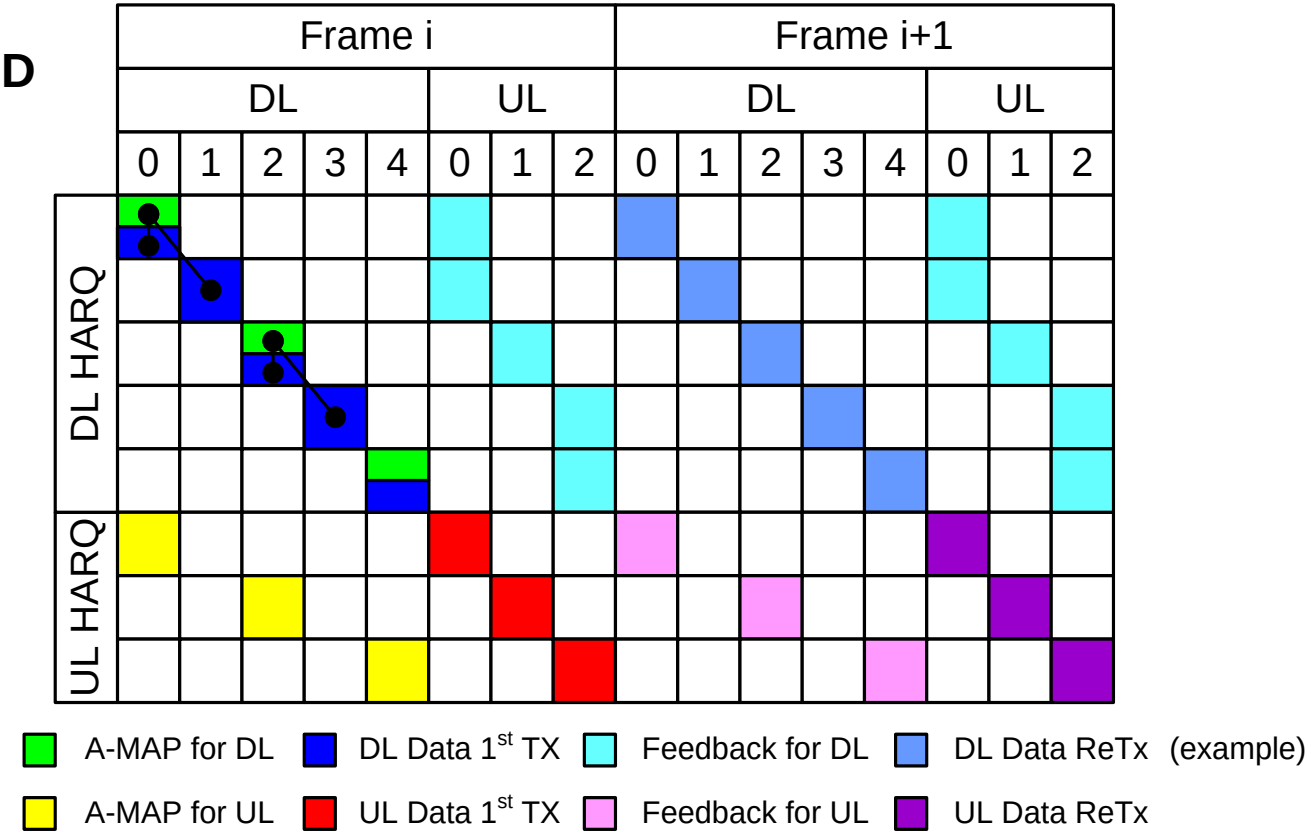
- The same equation applied



- The timing above provides a time gap of at least 2 subframes for Tx/Rx processing
- The gray-filled square indicates the expected timing but no transmission due to a too short Tx/Rx interval (1 subframe)
- If a longer time gap (3 subframes) should be secured, a slow interlace is applied

A-MAP Tx Period = 2 subframes

5:3 TDD



- The timing above provides a time gap of at least 2 subframes for Tx/Rx processing
- If a longer time gap (3 subframes) should be secured,

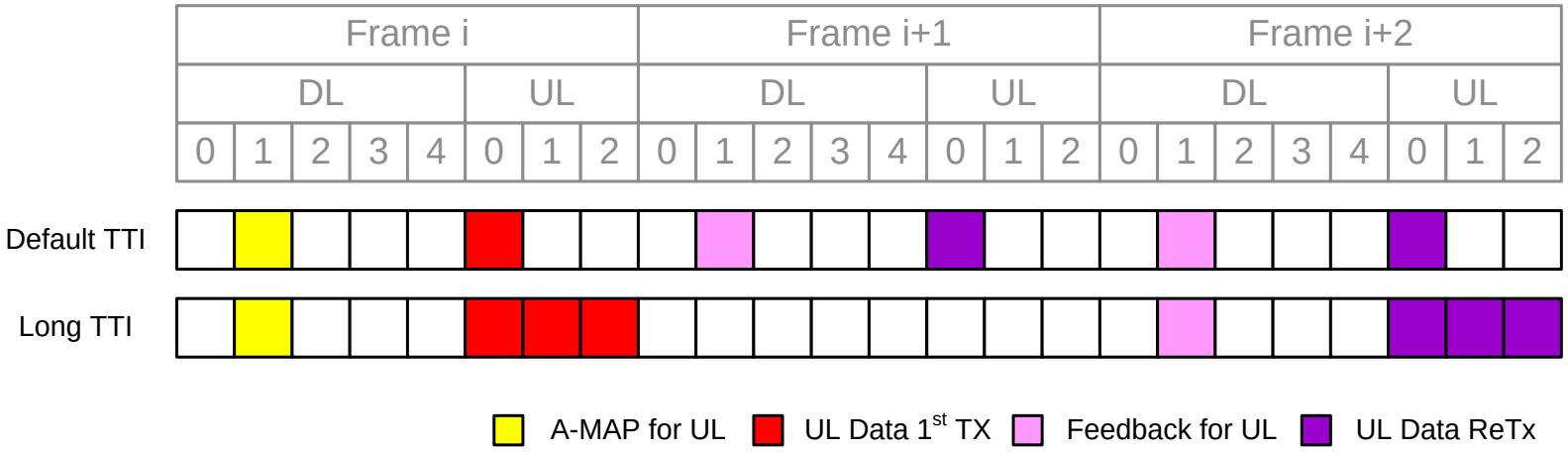
  DL: a slow interlace is applied to subframe DL4

  UL: a slow interlace is applied to subframe UL0 and UL2

Long TTI Transmission

- Apply the same equation and rule as the default TTI transmission
  - Subframe index (m) of data transmission indicates the 1st subframe occupied by the long TTI burst
  - The slow feedback/interlace is applied
  - Long TTI size = 4 subframes (FDD), the whole DL/UL subframes (TDD)

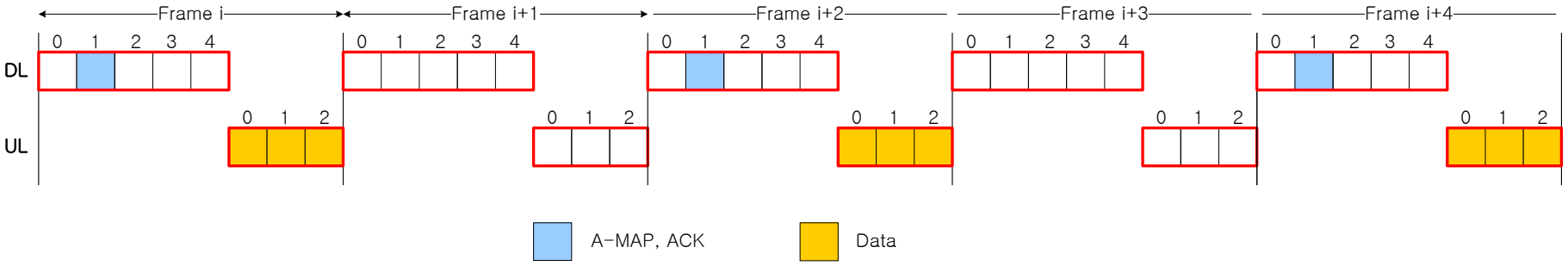
- Example of HARQ timing for a UL long TTI Tx



Periodic HARQ Timing for Long TTI Tx

- Even for the long TTI Tx, A periodic Rx/Tx (duty cycle) is provided
  - **Benefit to Power Saving and CLC support**

- Example of UL Long TTI Transmission
  - UL A-MAP and DL-ACK are transmitted in same DL subframe.
  - **So, MS needs to be active only in DL subframe #1**

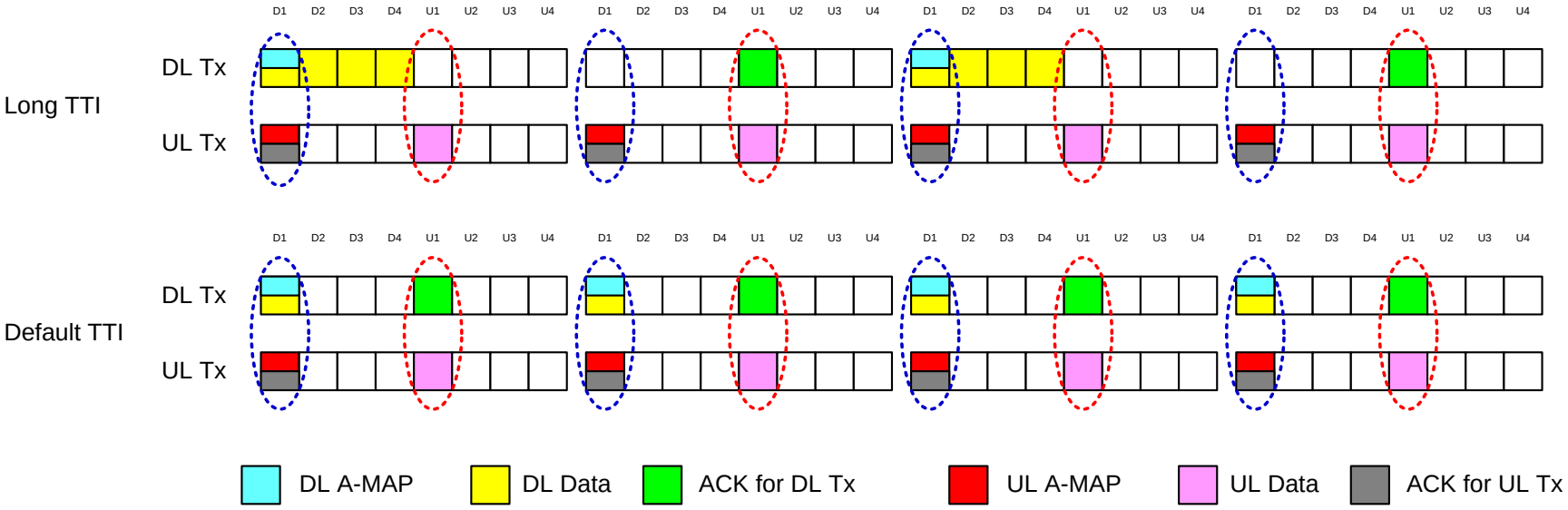


Synchronized Active Cycle in Long TTI Tx and Default Tx

- Benefit to Power Saving and CLC
- Regardless of DL data TTI, the same UL subframe for DL HARQ ACK

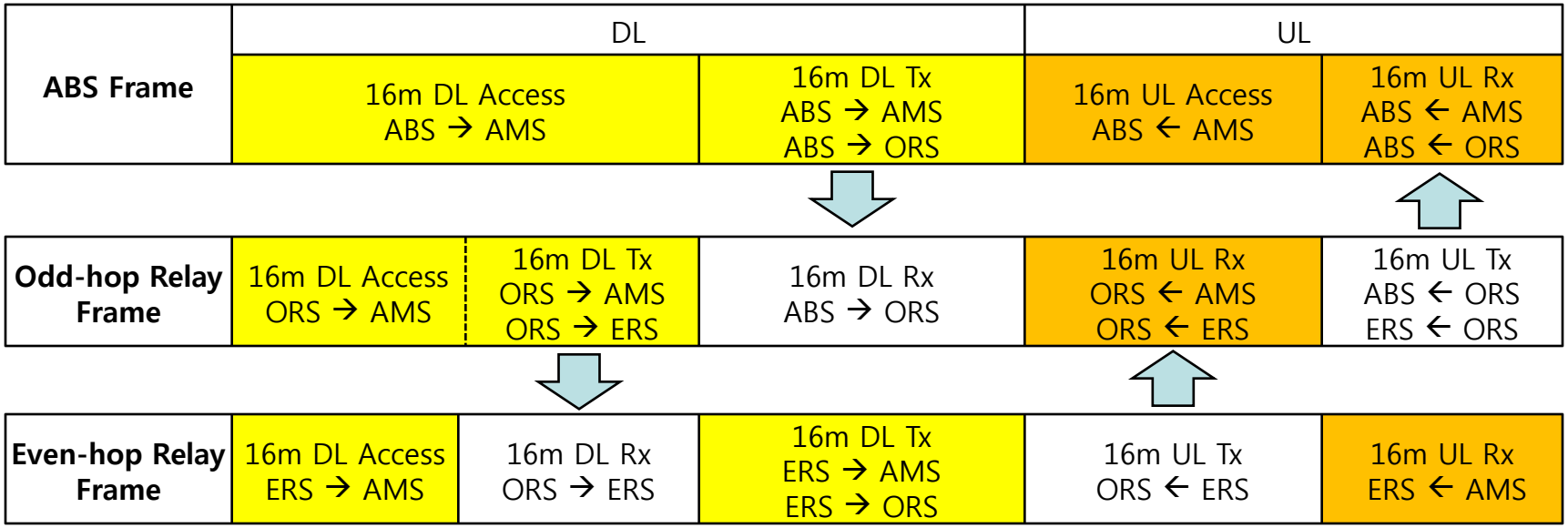
  ⇒ *Maximize power saving and Keep the same CLC pattern in UL*
- At the same time, DL A-MAP and UL A-MAP in the same DL subframe

  ⇒ *Keep the same micro-sleep pattern in DL (only to monitor one DL subframe)*



Relay Support

- Apply the proposed HARQ time to active DL/UL zones btw ARS and AMS
  - Index of subframes within active zones is renumbered
- Relay Frame Structure (exclude Network coding zone) in section 11.4.3 in SDD*



ABS: Advanced BS. AMS: Advanced MS, ORS: Odd-hop ARS, ERS: Even-hop ARS

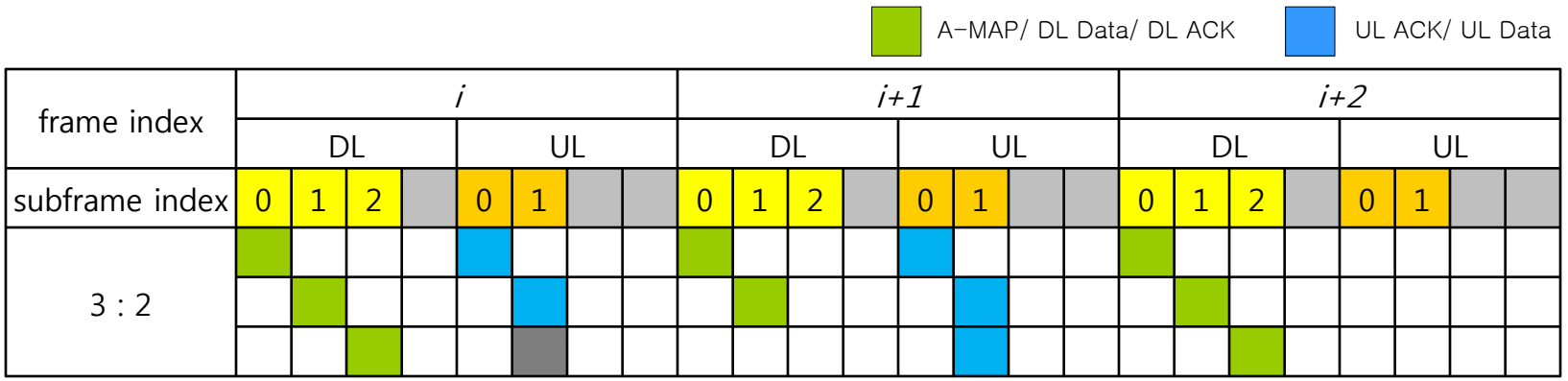
*Refer to C802.16m-09/003r8

Relay Support –TDD 4 : 4 (1/2)

- Odd-hop Relay Frame Structure in TDD 4 : 4

Odd-hop Relay	DL				UL			
	16m DL Access/Tx ORS → AMS			16m DL Rx BS → ORS	16m UL Access ORS ← AMS		16m UL Rx RS(BS) ← ORS	
subframe index	0	1	2		0	1		

⇒D:U = 3:2 at 16m odd-hop Relay (the same equation applied)



- The gray-filled square indicates the expected timing but no transmission due to a too short Tx/Rx interval (2 subframe). Assume Tx/Rx processing time = 3 subframes

Relay Support –TDD 4 : 4 (2/2)

- Even-hop Relay Frame Structure in TDD 4 : 4

Even-hop Relay	DL				UL			
	16m DL Access ERS →AMS	16m DL Access ERS → AMS		16m DL Tx ERS →AMS	16m UL Tx ERS ← ORS		16m UL Rx ERS ← AMS	
subframe index	0			1			0	1

⇒D:U = 2:2 at 16m even-hop Relay (the same equation applied)