

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

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“802.16m AWD”

IEEE 802.16m-09/0012, “Call for Contributions on Project 802.16m Amendment Working Document (AWD) Content”.

- Call for Contributions for P802.16m AWD Proposals: Target topic – HARQ timing.

Base Contribution:

None

Purpose:

To be discussed and adopted by TGM for the 802.16m Amendment Working Document

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

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March 2009

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-09/0539](#)

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 require a fixed HARQ feedback delay
 - HARQ Retransmission Time
 - Synchronous HARQ in UL requires a fixed HARQ RTT
 - A fixed HARQ RTT is of benefit to power saving even in DL with asynchronous HARQ

Design Requirements

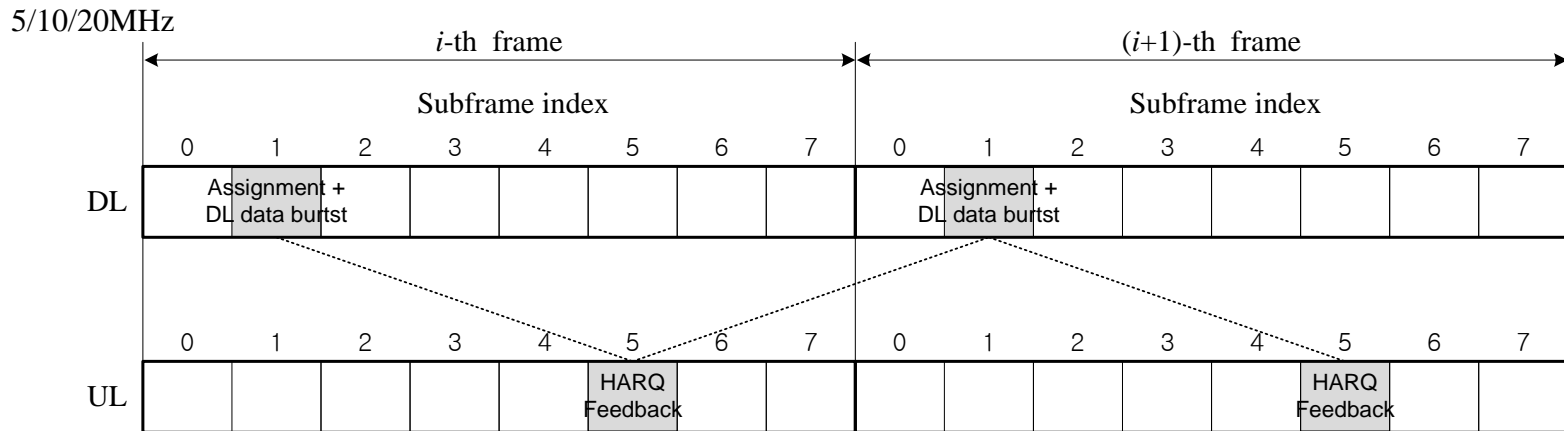
HARQ timing should be ...

- 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

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

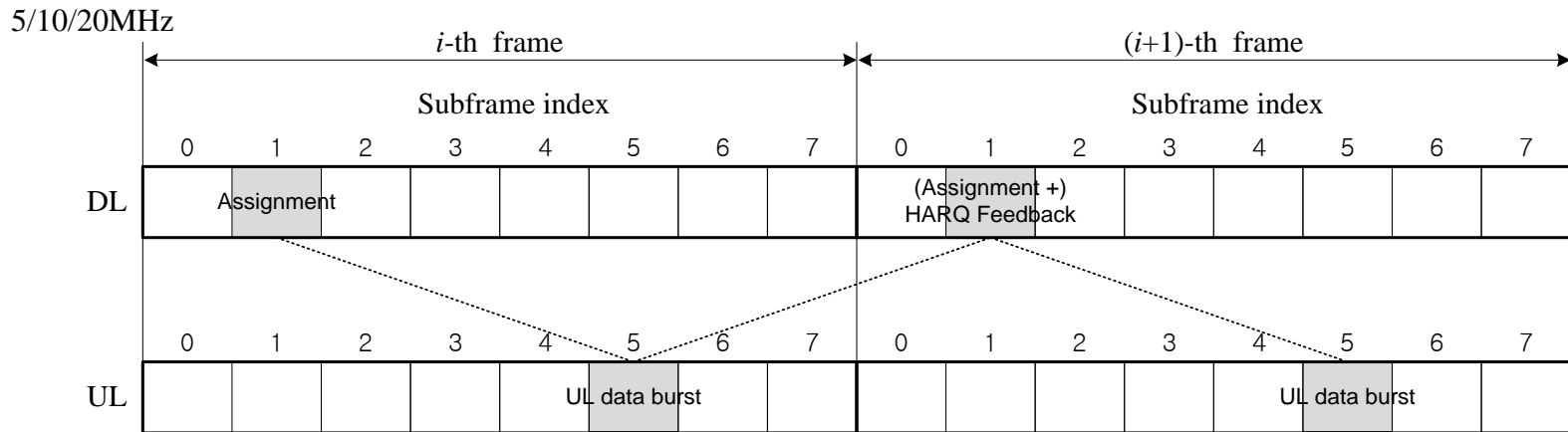
HARQ Timing in FDD DL



Content	Subframe index	Frame index
Tx of Assignment IE in DL	l	i
Data burst Tx in DL	$m = \begin{cases} l, & \text{for } N_{A-MAP} = 1 \\ l \text{ or } l + 1, & \text{for } N_{A-MAP} = 2 \end{cases}$	i
HARQ feedback in UL	$n = \text{ceil}(m+F/2) \bmod F$	$j = (i + \text{floor}(\text{ceil}(m+F/2)/F) + z) \bmod 4$

- N_{A-MAP} : A-MAP transmission period
- F : num of subframe / frame (8 for 5/10/20MHz, 7 for 8.75MHz, 6 for 7MHz)
- z : DL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 12)

HARQ Timing in FDD UL

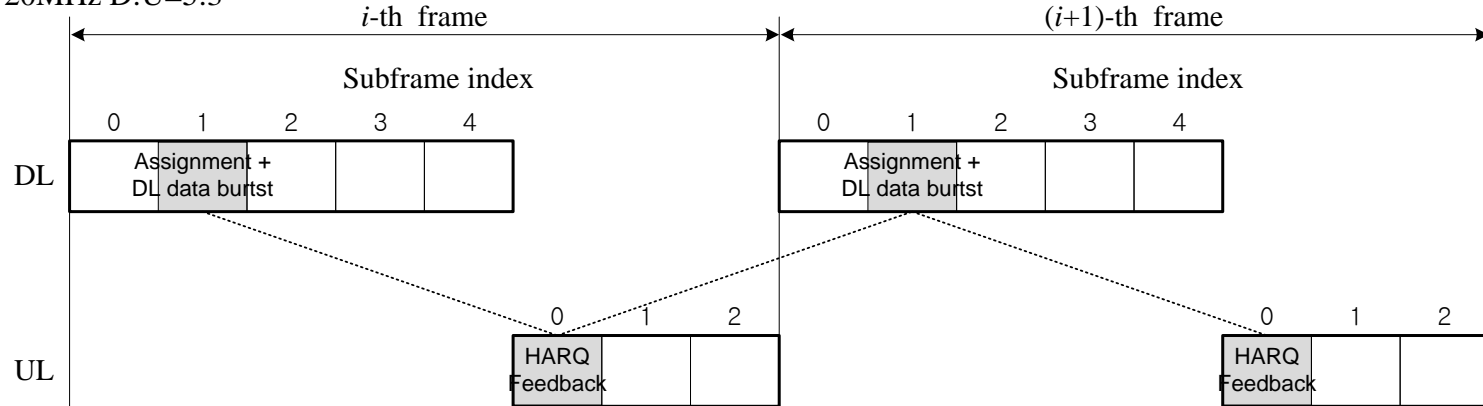


Content	Subframe index	Frame index
Tx of Assignment IE in DL	l	i
Data burst Tx in UL	$m = \begin{cases} n, & \text{for } N_{A-MAP} = 1 \\ n \text{ or } n + 1, & \text{for } N_{A-MAP} = 2 \end{cases}$ <p>where $n = \text{ceil}(l + F/2) \bmod F$</p>	$j = (i + \text{floor}(\text{ceil}(l + F/2)/F) + \nu) \bmod 4$
HARQ feedback in DL	l	$k = (j + \text{floor}((m + F/2)/F) + w) \bmod 4$
Data burst Tx in UL	m	$p = (k + \text{floor}(\text{ceil}(l + F/2)/F) + \nu) \bmod 4$

- N_{A-MAP} : A-MAP transmission period
- F : num of subframe / frame (8 for 5/10/20MHz, 7 for 8.75MHz, 6 for 7MHz)
- w : UL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 13)
- ν : UL HARQ Tx offset - 0 for fast Tx timing, 1 for slow Tx timing (see the slide 13)

HARQ Timing in TDD DL

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



Content	Subframe index	Frame index
Tx of Assignment IE in DL	l	i
Data burst Tx in DL	$m = \begin{cases} l, & \text{for } N_{A-MAP} = 1 \\ l \text{ or } l + 1, & \text{for } N_{A-MAP} = 2 \end{cases}$	i
HARQ feedback in UL	$\text{For } D \geq U, \quad n = \begin{cases} 0, & \text{for } 0 \leq m < K \\ m - K, & \text{for } K \leq m < U + K \\ U - 1, & \text{for } U + K \leq m < D \end{cases}$ $\text{For } D < U, \quad n = m - K$	$j = (i+z) \bmod 4$

- N_{A-MAP} : A-MAP transmission period
- z : DL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 12)

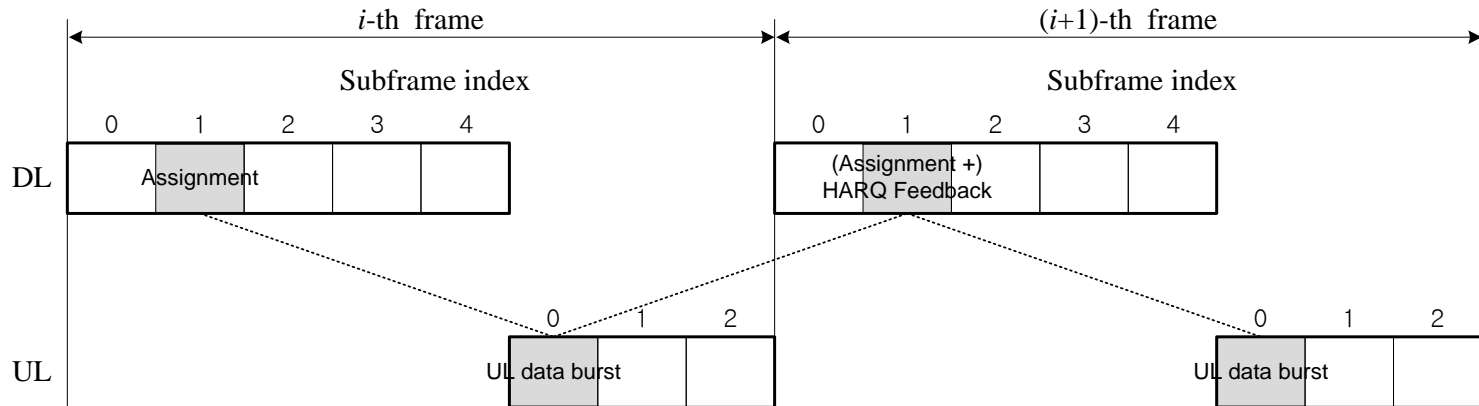
HARQ Timing in TDD UL (1/2)

Content	Subframe index	Frame index
Tx of Assignment IE in DL	l	i
Data burst Tx in UL	<p>For $\text{ceil}(D/N_{A-MAP}) \geq U$,</p> $m = \begin{cases} 0, & \text{for } 0 \leq l < K \\ l - K, & \text{for } K \leq l < U + K \\ U - 1, & \text{for } U + K \leq l < D \end{cases}$ <p>For $\text{ceil}(D/N_{A-MAP}) < U$,</p> <p>For $N_{A-MAP} = 1$,</p> $m = \begin{cases} 0 \text{ or } 1, & \text{for } l = 0 \\ l - K, & \text{for } 0 < l < D - 1 \\ U - 1, & \text{for } l = D - 1 \end{cases}$ <p>For $N_{A-MAP} = 2$,</p> $m = \begin{cases} 0 \text{ or } 1, & \text{for } l = 0 \\ l - K \text{ or } l - K + 1, & \text{for } 0 < l < D - 1 \\ U - 1, & \text{for } l = D - 1 \end{cases}$	$j = (i+v) \bmod 4$
HARQ feedback in DL	l	$k = (j+1+w) \bmod 4$
Data burst ReTx in UL	m	$p = (k+v) \bmod 4$

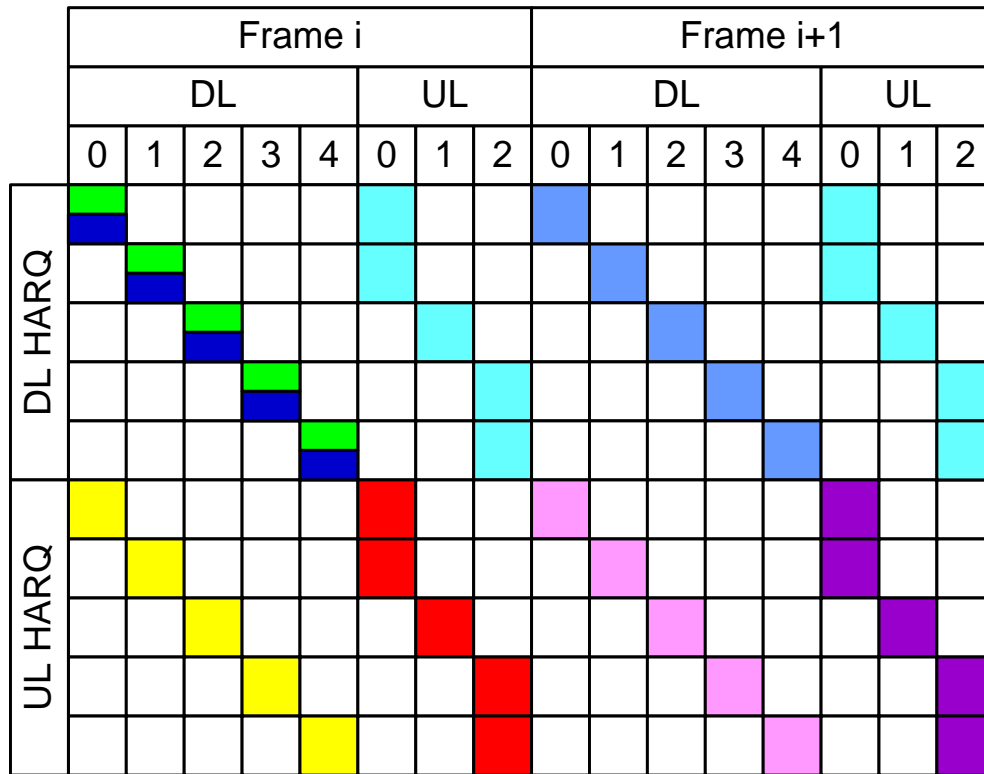
- N_{A-MAP} : A-MAP transmission period
- w : UL HARQ feedback offset - 0 for fast feedback timing, 1 for slow feedback timing (see the slide 13)
- v : UL HARQ Tx offset - 0 for fast Tx timing, 1 for slow Tx timing (see the slide 13)

HARQ Timing in TDD UL (2/2)

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

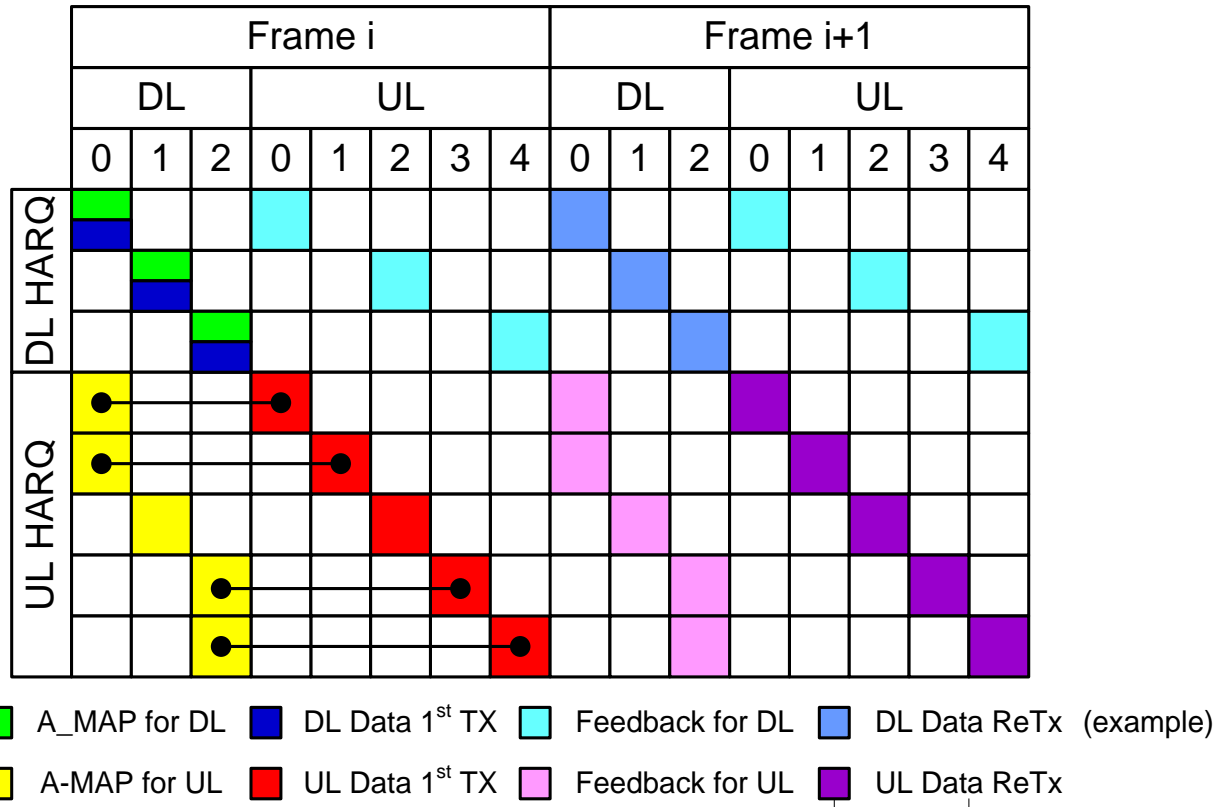


HARQ Timing Illustration – TDD 5:3



- 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.

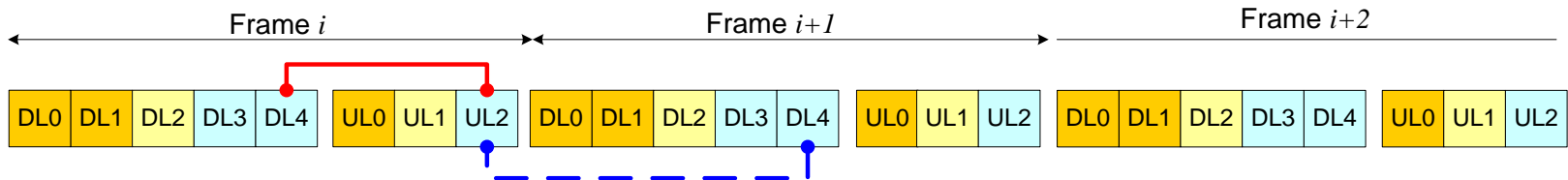
HARQ Timing Illustration – TDD 3:5



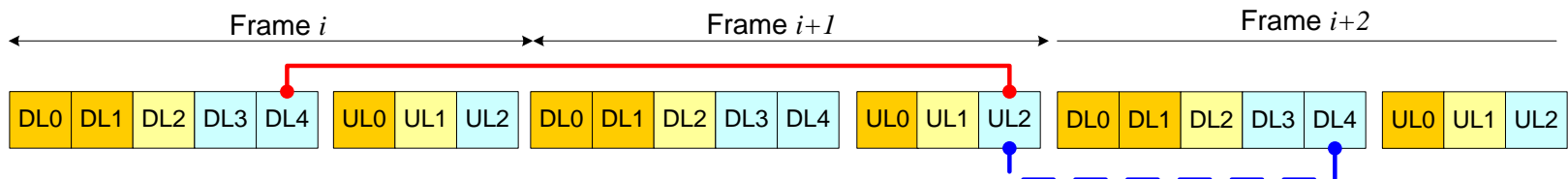
- Both A-MAPs for UL0 and UL1 are transmitted in the same DL subframe (DL0)
- So, UL A-MAP IE shall include an indication of the assigned UL subframe

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



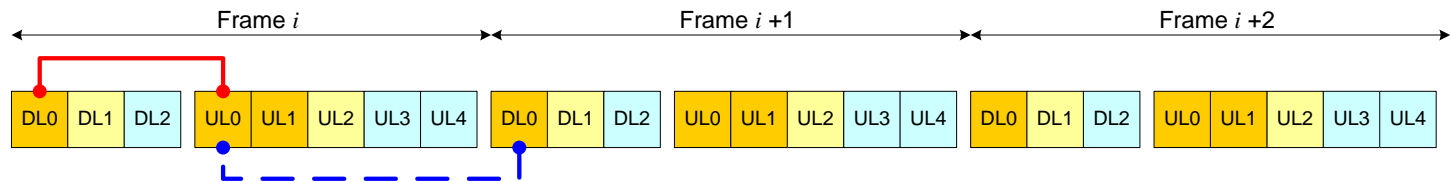
Two HARQ Timing Options (UL)

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

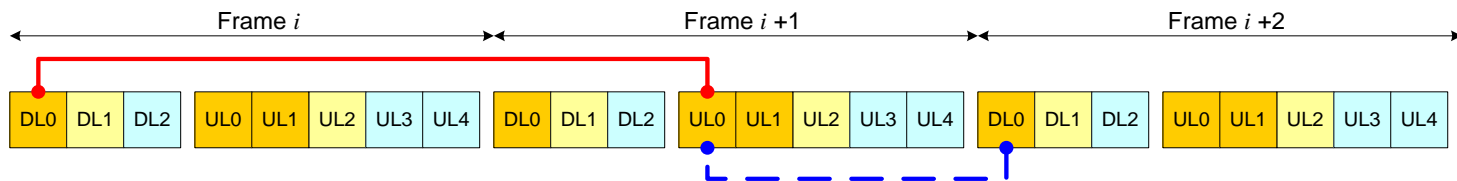
- ① Fast transmission : $v = 0$,
- ② Slow transmission : $v = 1$

- 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 in 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/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)

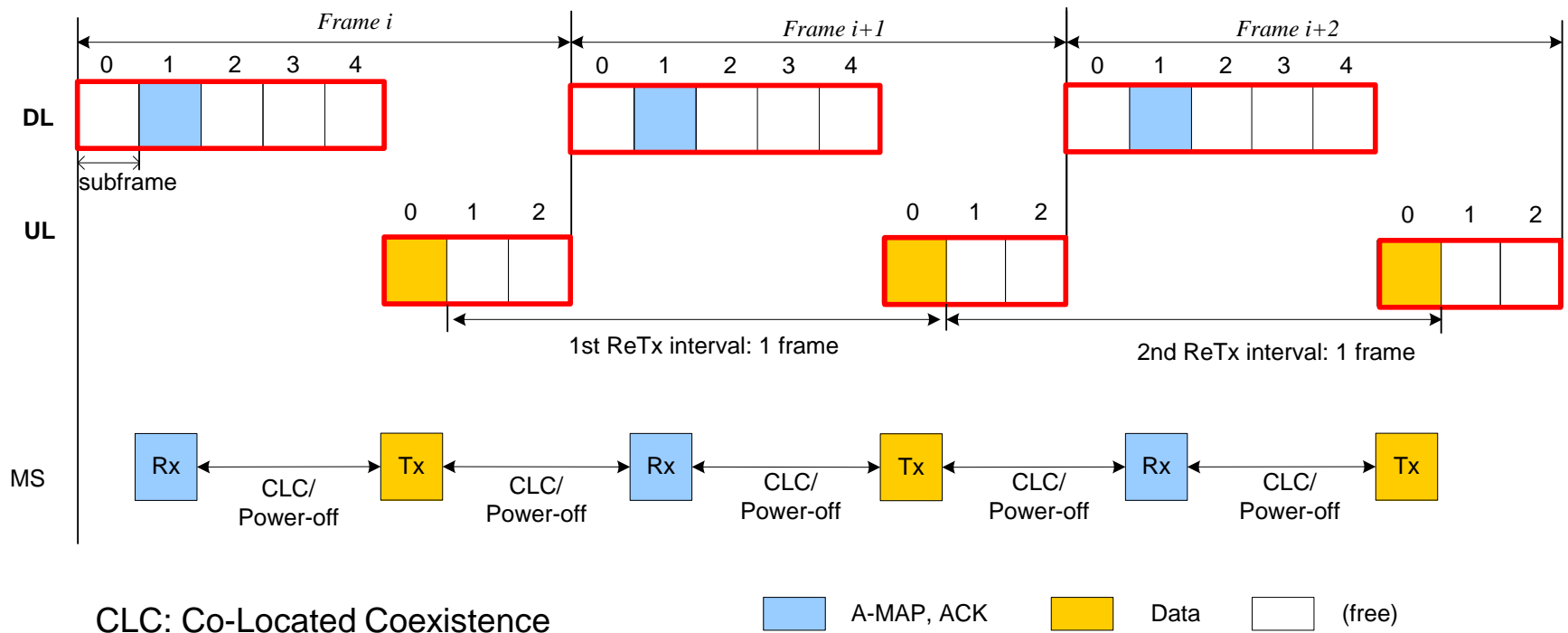
Features/Benefits of the Proposal

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

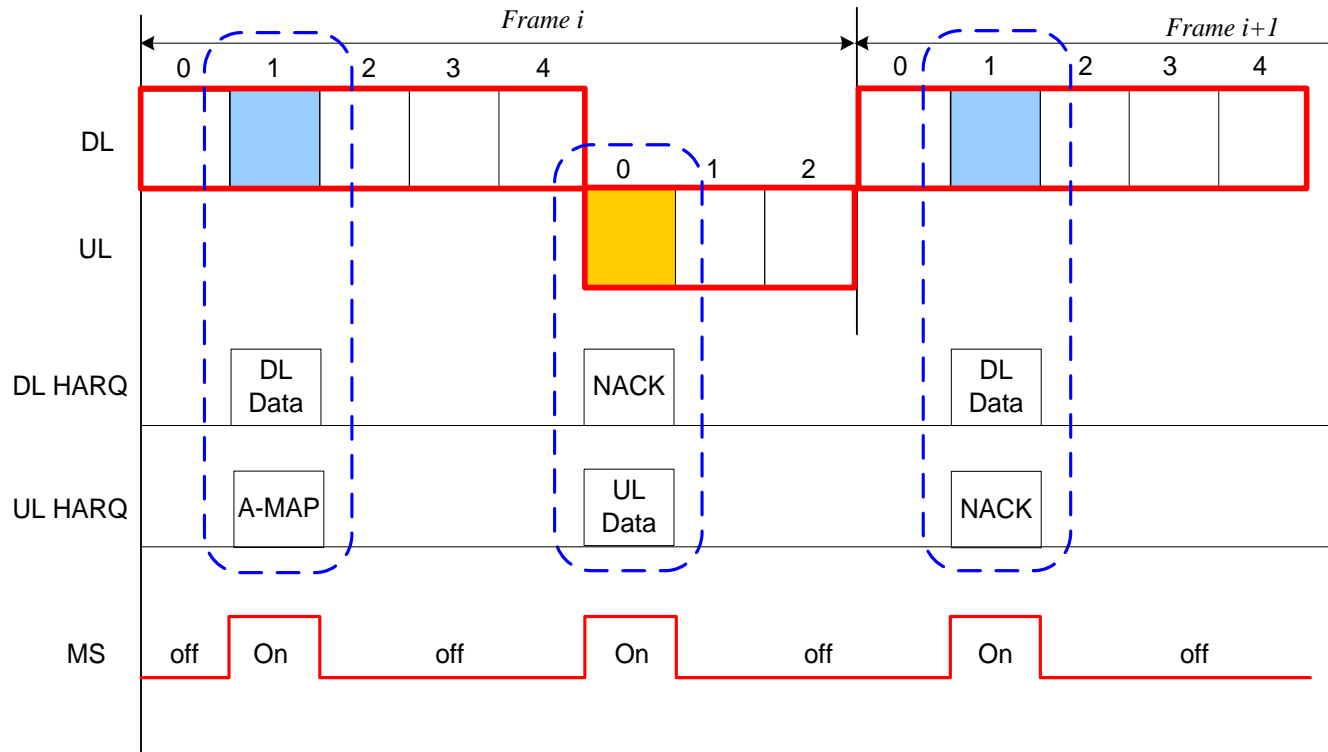
Periodic HARQ Timing

- 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

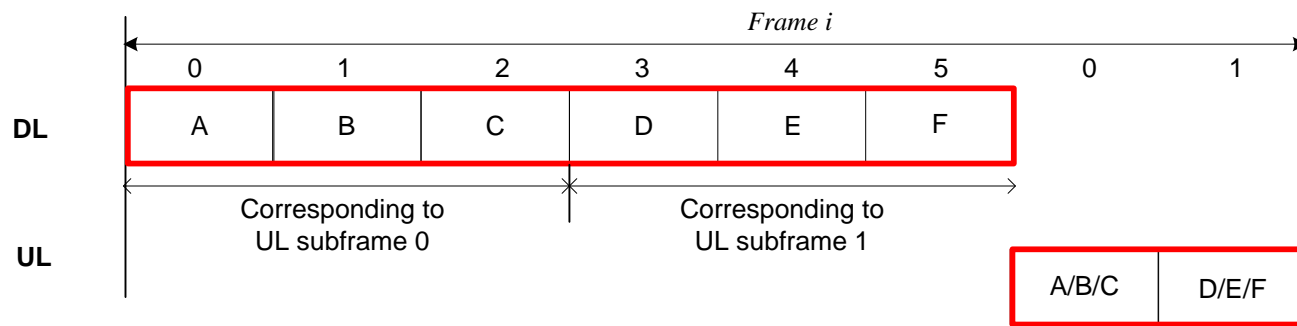


Note: MS is active only in DL subframe #1 and UL subframe #0; 1/4 activity

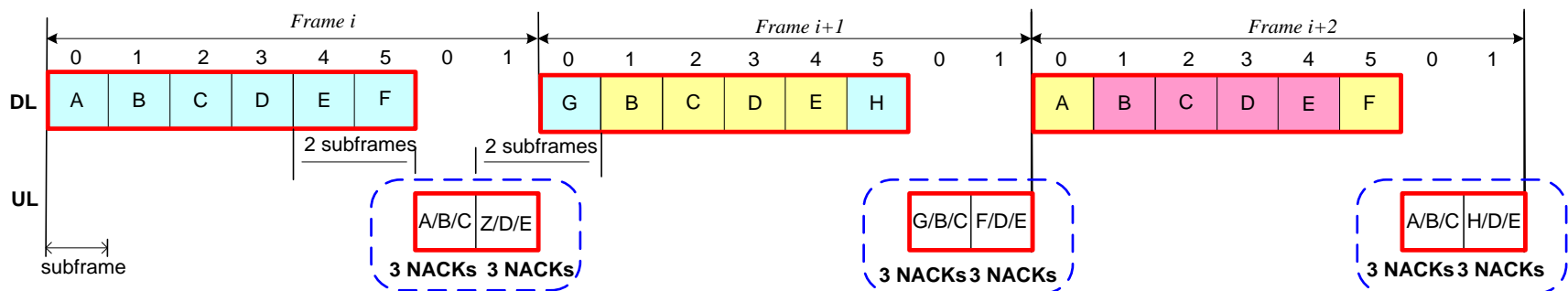
Uniformly-Distributed Feedbacks

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

6 : 2 TDD



6 : 2 TDD, 2 subframe processing time



5ms RTT: B, C, D, E

10ms RTT: A, F, G, H

Initial Tx 1st Re-Tx 2nd Re-Tx

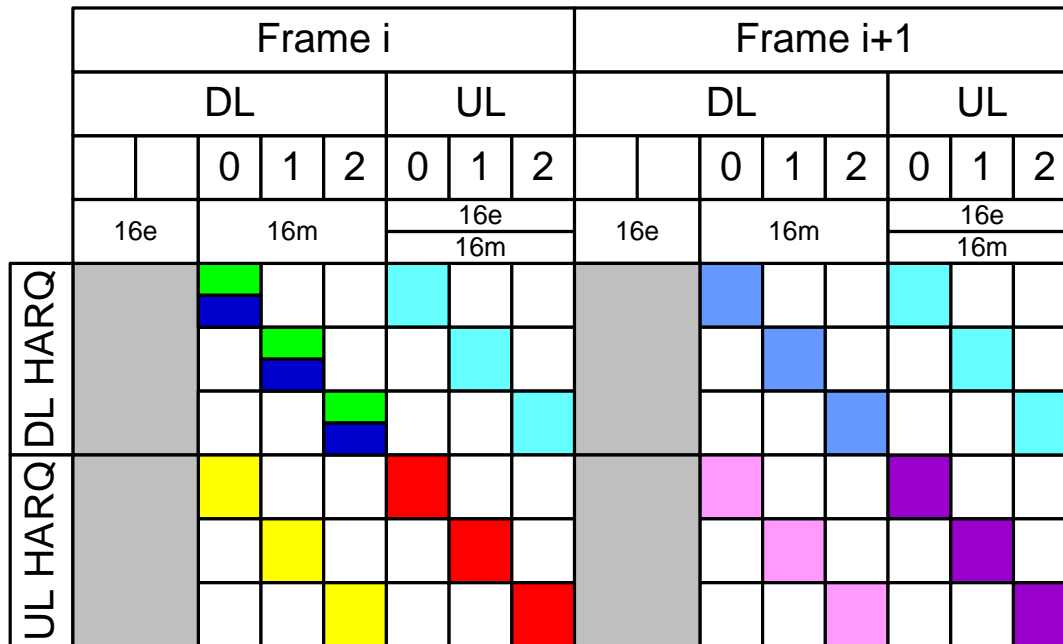
Appendix: HARQ timing illustration for ...

- 1) Legacy Support
- 2) 8.75MHz, 7MHz Frames
- 3) A-MAP Tx period = 2
- 4) Long TTI transmission

Legacy Support – TDD 5:3 (1/2)

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

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

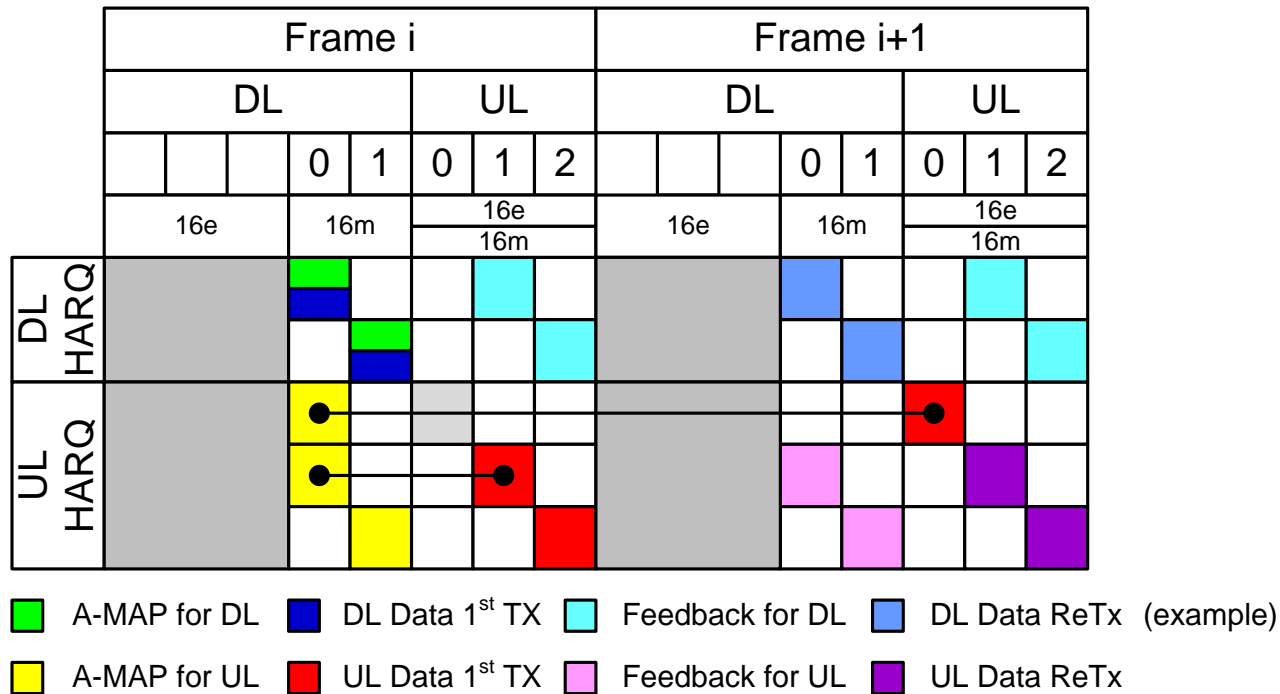


- A-MAP for DL
- DL Data 1st TX
- Feedback for DL
- DL Data ReTx (example)
- A-MAP for UL
- UL Data 1st TX
- Feedback for UL
- UL Data ReTx

Legacy Support – TDD 5:3 (2/2)

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

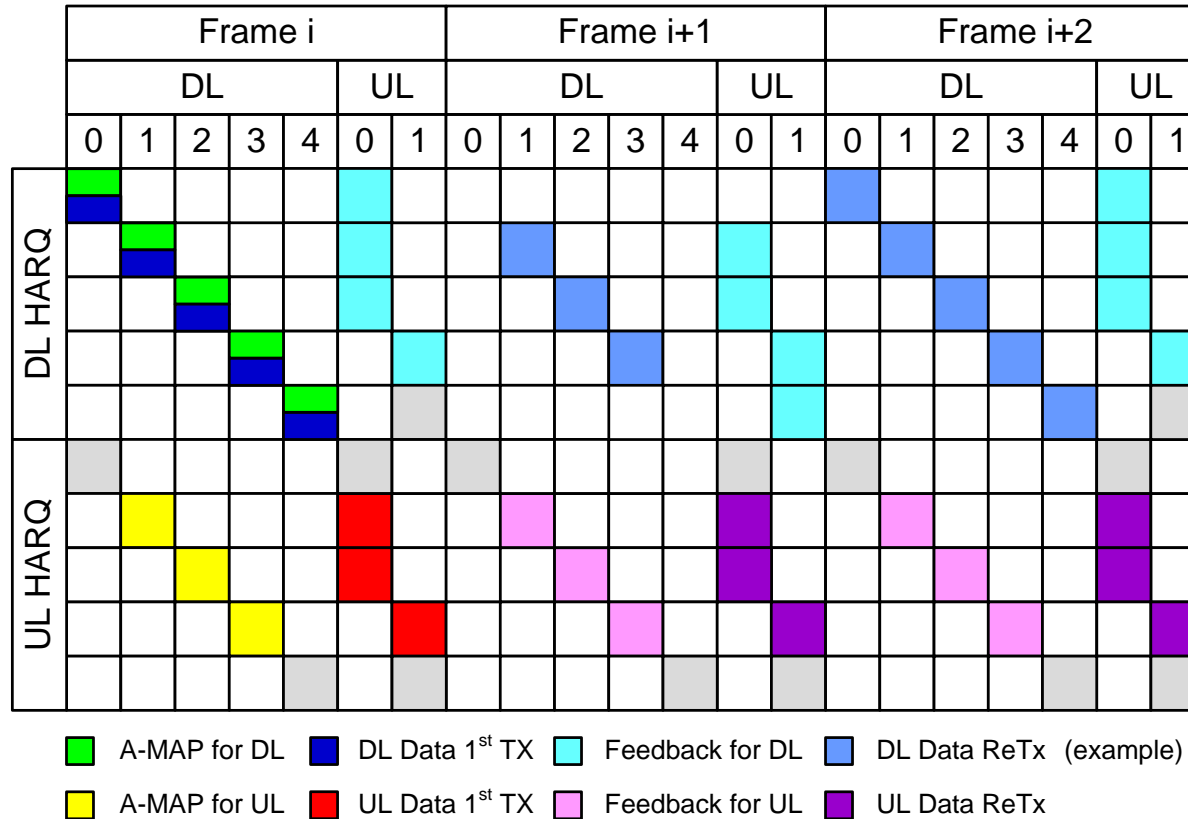
⇒ D:U = 2:3 at 16m (the same equation applied)



- 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)

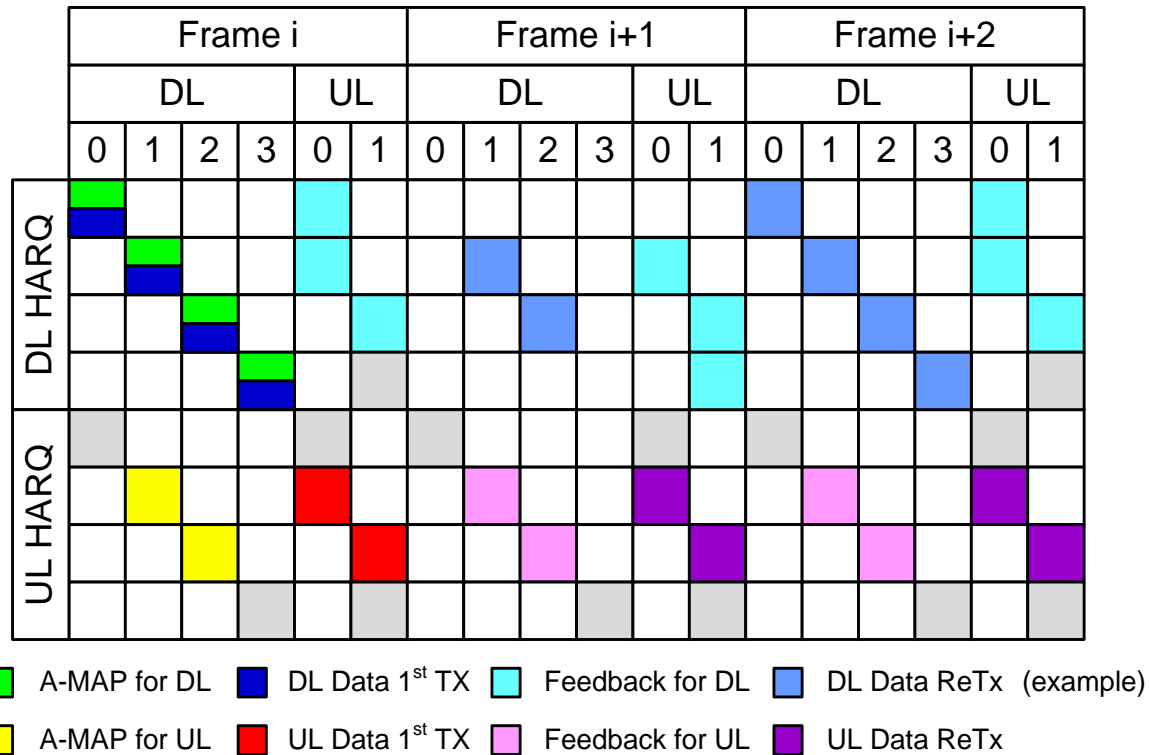
- The same equation applied [For the details of 8.75MHz frame structure, see IEEE C802.16m-09/0275r1]



- 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)

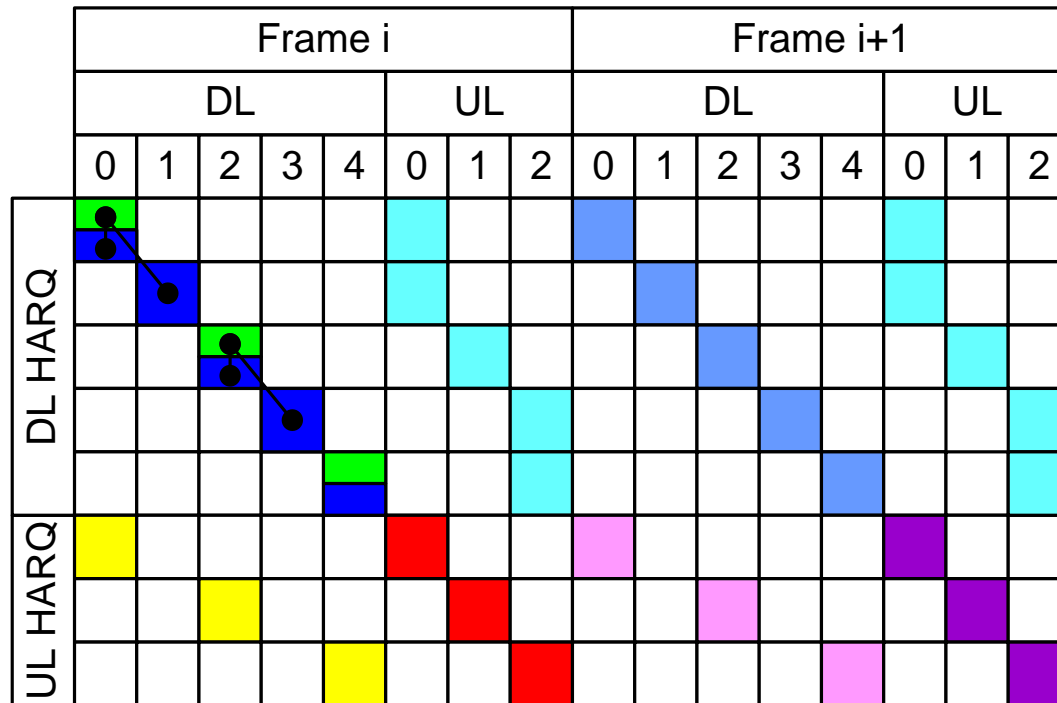
- The same equation applied [For the details of 7MHz frame structure, see IEEE C802.16m-09/0275r1]



- 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



- Green: A-MAP for DL
- Blue: DL Data 1st TX
- Cyan: Feedback for DL
- Light Blue: DL Data ReTx (example)
- Yellow: A-MAP for UL
- Red: UL Data 1st TX
- Pink: Feedback for UL
- Purple: UL Data ReTx

- 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)
- [for more details, see IEEE C802.16m-09/0536]
- Example of HARQ timing for a UL long TTI Tx

