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

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None

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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

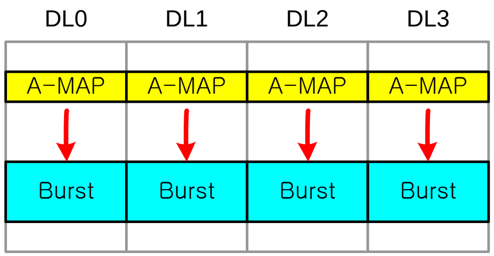
# HARQ Timings

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

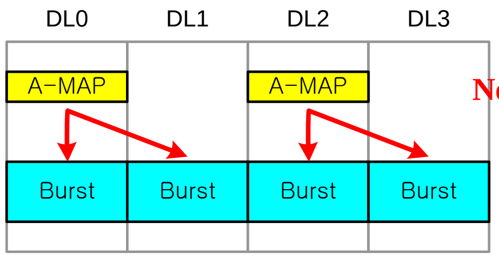
- Open issue: the detailed timing of HARQ operation
  - HARQ Feedback Delay
    - Both synchronous and asynchronous HARQ benefit from a predefined HARQ feedback delay
  - HARQ Retransmission Time
    - Synchronous HARQ in UL requires a predefined HARQ ReTx interval
    - The predefined HARQ ReTx interval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

# A-MAP Relevance

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



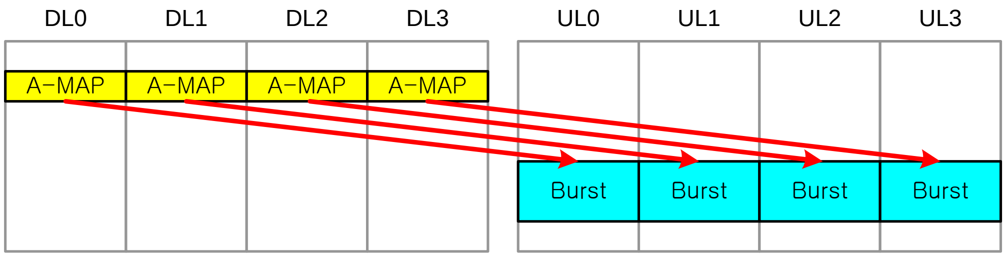

A-MAP Tx period = 2




**Need an explicit indication**

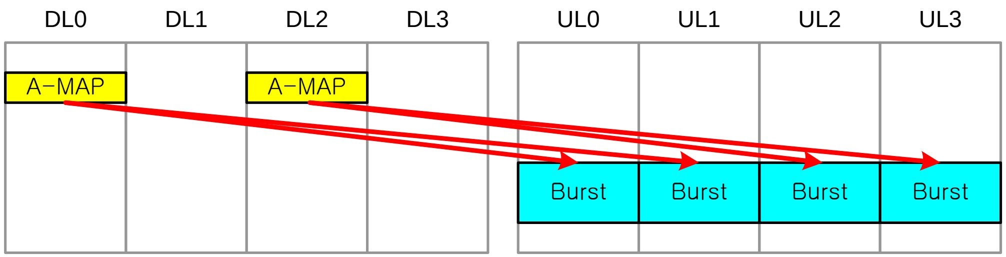
- UL A-MAP Relevance
  - A-MAP Tx period = 1

**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

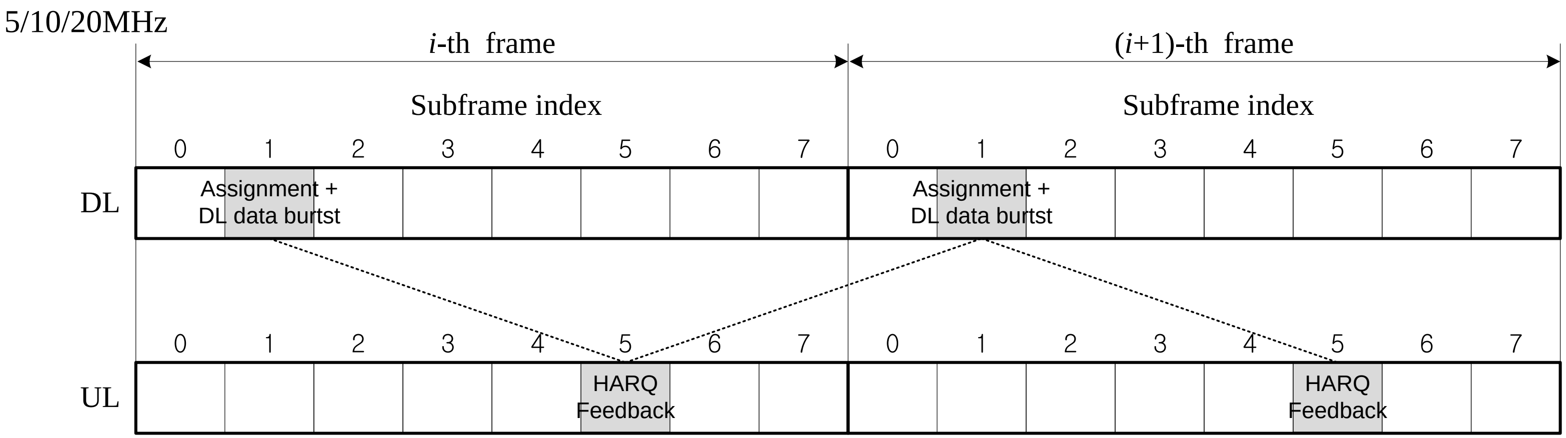
  ② Tx processing time at MS includes …
    - UL A-MAP or ACK/NACK decoding, Data burst encoding

  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

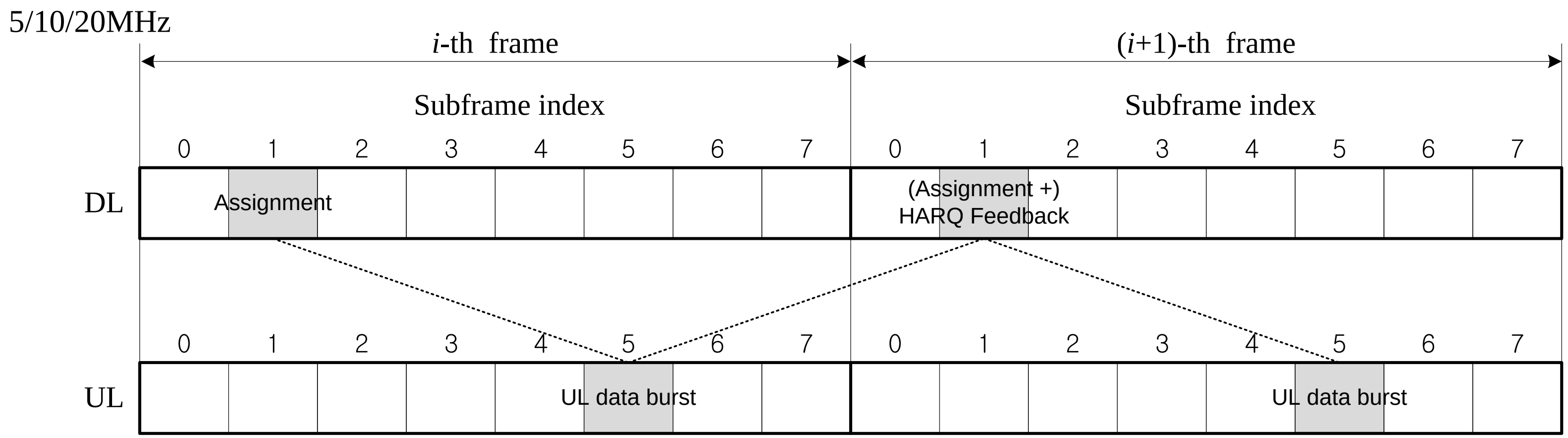
# HARQ Timing in FDD DL




| 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)

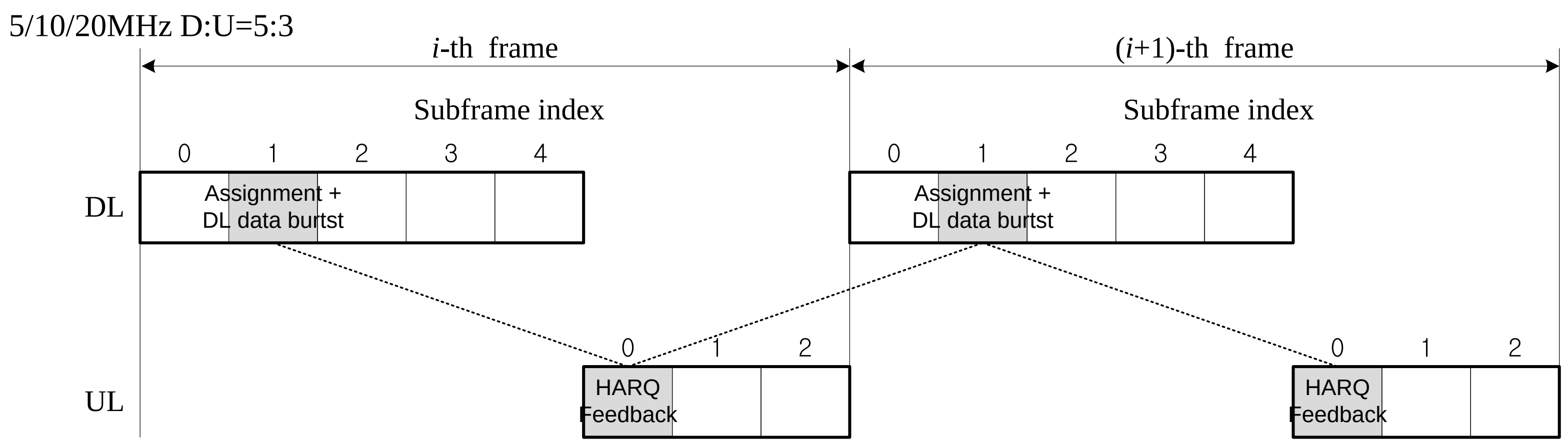
# HARQ Timing in FDD UL




| 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 $n$ = ceil($l$+$F$/2) mod $F$ | $j$ = ($i$+floor(ceil($l$+$F$/2)/$F$)+$v$) mod 4 |
| HARQ feedback in DL | $l$ | $k$ = ($j$+floor(($m$+$F$/2)/$F$)+$w$) mod 4 |
| HARQ Subpacket Re-Tx in UL | $m$ | $p$ = ($k$+floor(ceil($l$+$F$/2)/$F$)+$v$) 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)
- $v$ : 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 | $m = l \text{ or } l + N_{A-MAP} - 1$ | $i$ |
| HARQ feedback in UL | For $D > U$, $n = \begin{cases} 0, & \text{for } 0 \le m < K \\ m - K, & \text{for } K \le m < U + K \\ U - 1, & \text{for } U + K \le m < D \end{cases}$<br>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 $D < U/N_{A\text{-}MAP}$, $K$ = ceil(($D$-$U$)/2) for $D \ge U$, and $K$ = –ceil(($U$-$D$)/2) for $D < U$. Otherwise, $K$ = floor(($D$-$U$)/2) for $D \ge U$, and $K$ = –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)

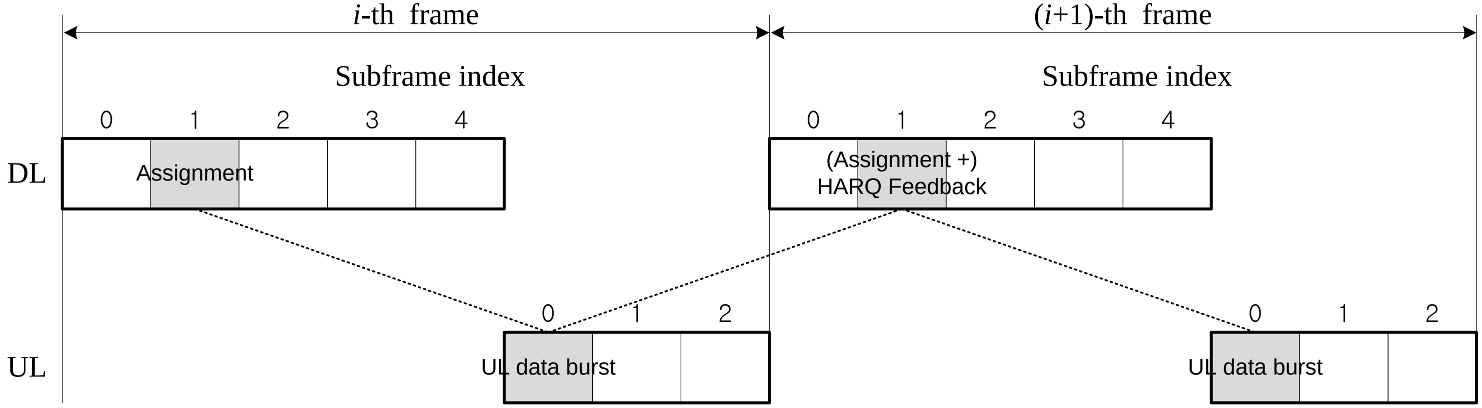
# HARQ Timing in TDD UL (1/2)

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

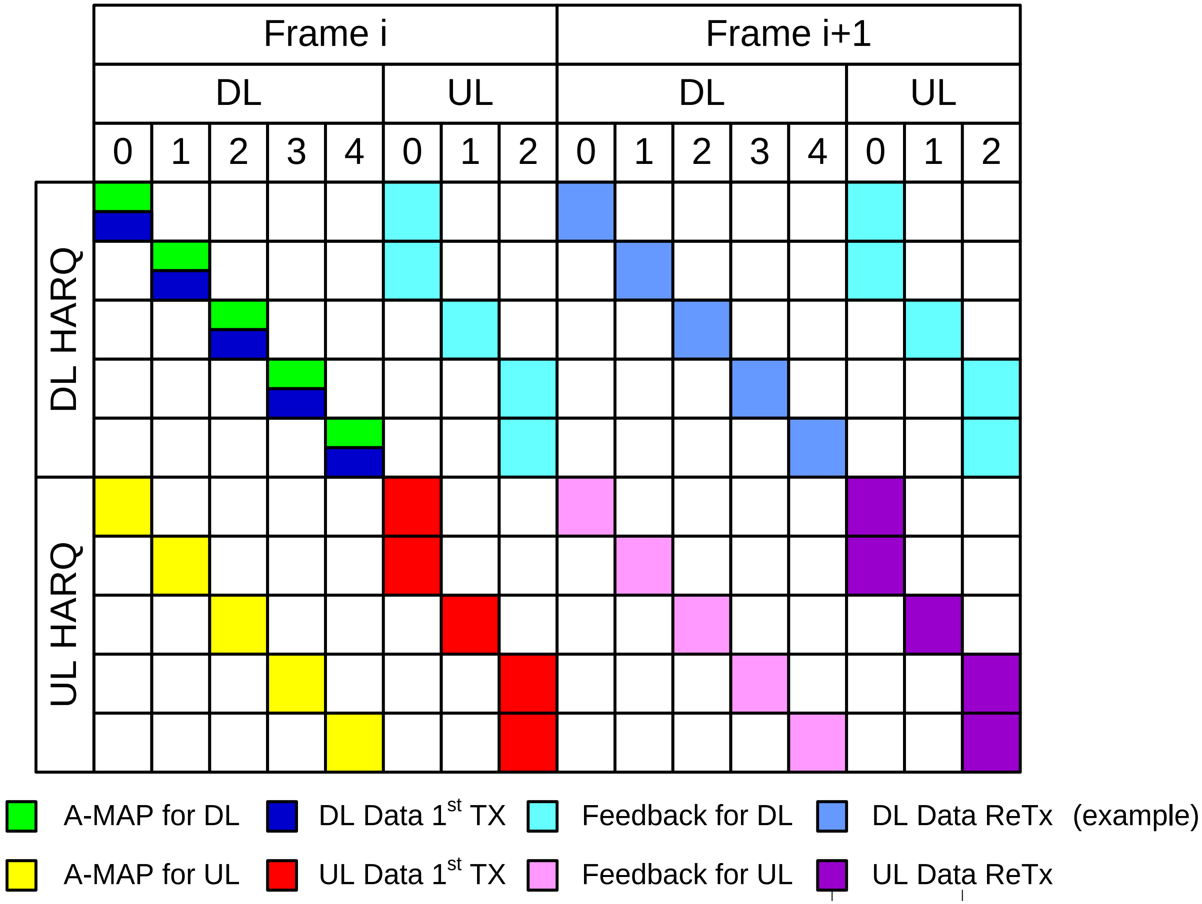
- $N_{A\text{-}MAP}$ : A-MAP transmission period,
- If $D+U$ is odd and $D < U/N_{A\text{-}MAP}$, $K$ = ceil(($D$-$U$)/2) for $D \geq U$, and $K$ = –ceil(($U$-$D$)/2) for $D < U$. Otherwise, $K$ = floor(($D$-$U$)/2) for $D \geq U$, and $K$ = –floor(($U$-$D$)/2) for $D < U$.
- $v$ : UL HARQ Tx offset - 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

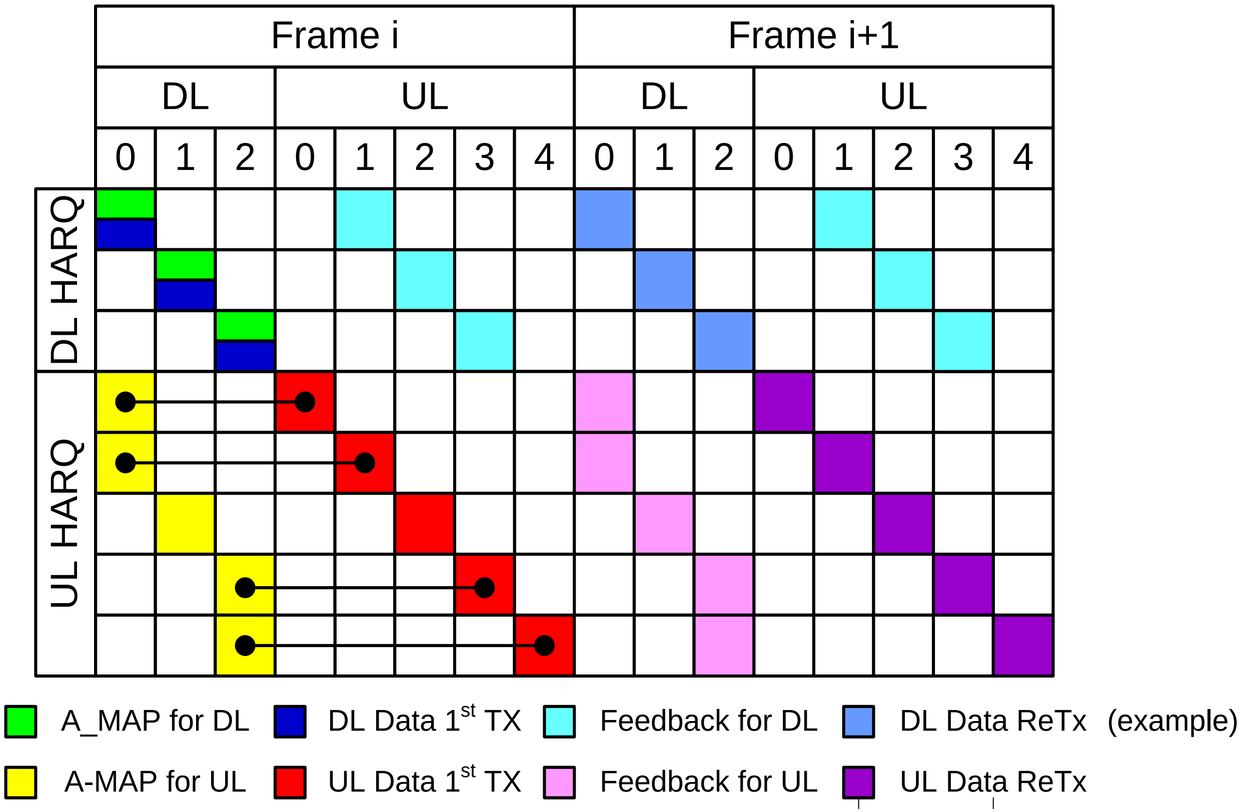



- The timing above provides a time gap of at least 2 subframes for Tx/Rx processing
- If a longer time gap (i.e. 3 subframes) should be secured,

  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

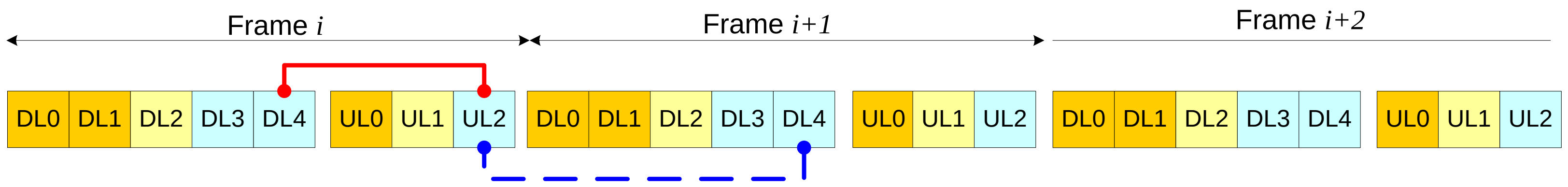



- Both A-MAPs for UL0 and UL1 are transmitted in the same DL subframe (DL0)
- So, UL A-MAP IE shall include an indication of the assigned UL subframe

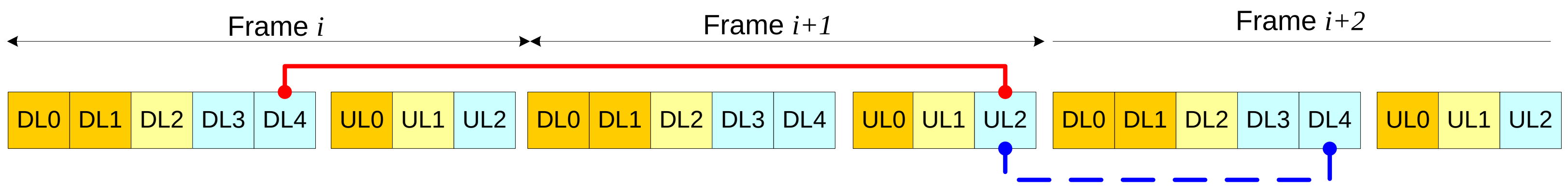
# Two HARQ Timing Options (DL)

- 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

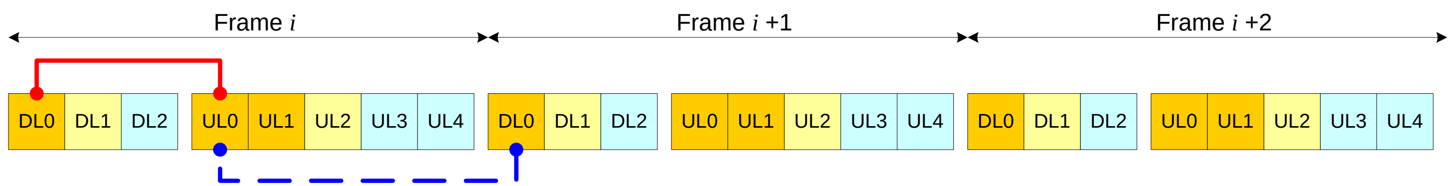



  - Else (Rx processing time = 3 subframe), the slow feedback ($z$ = 1) is applied

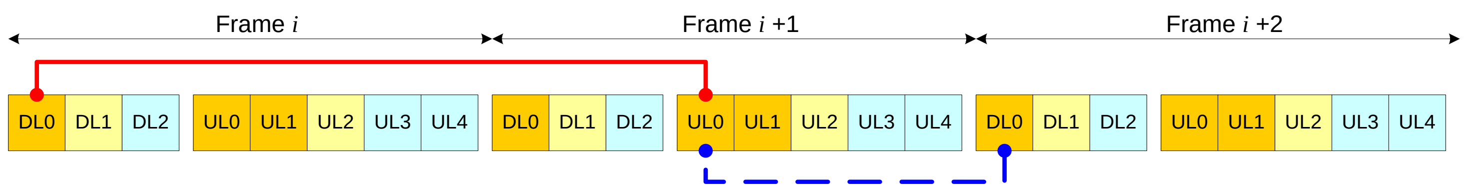


# Two HARQ Timing Options (UL)

- 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)**

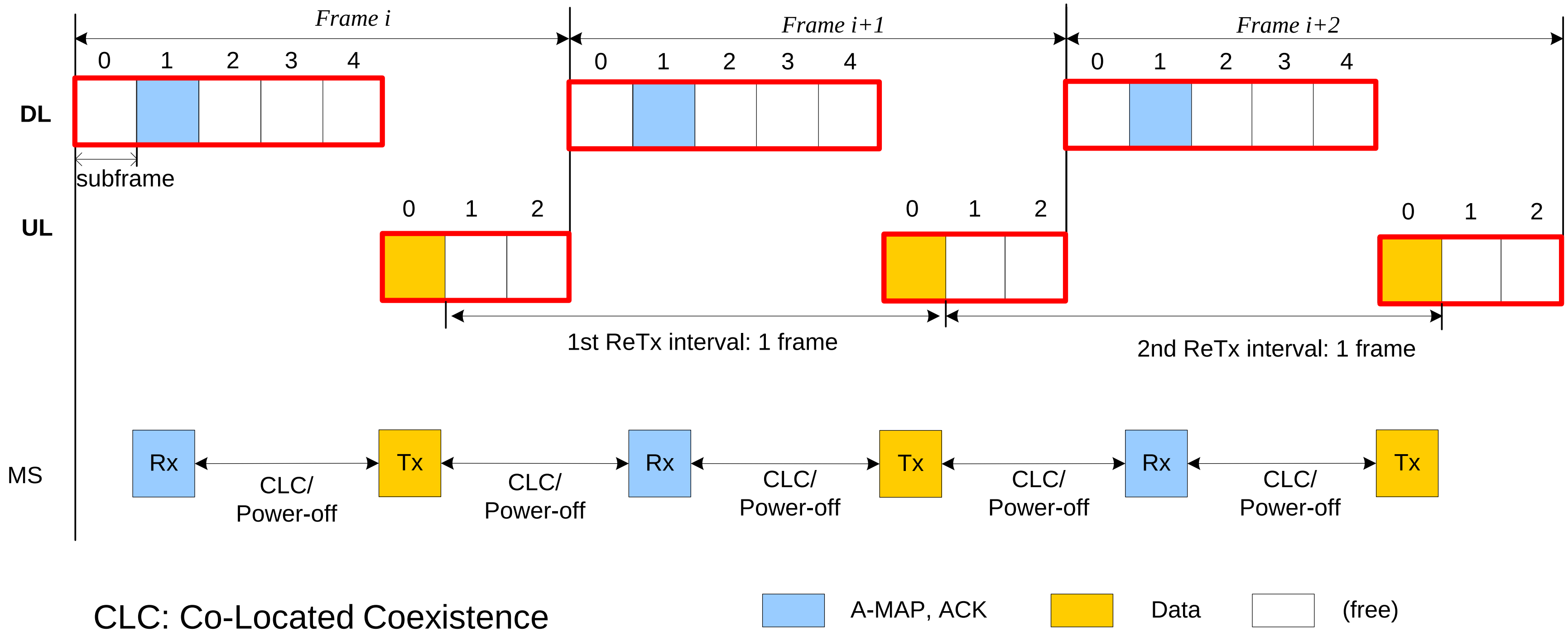
# Features/Benefits of the Proposal

*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”

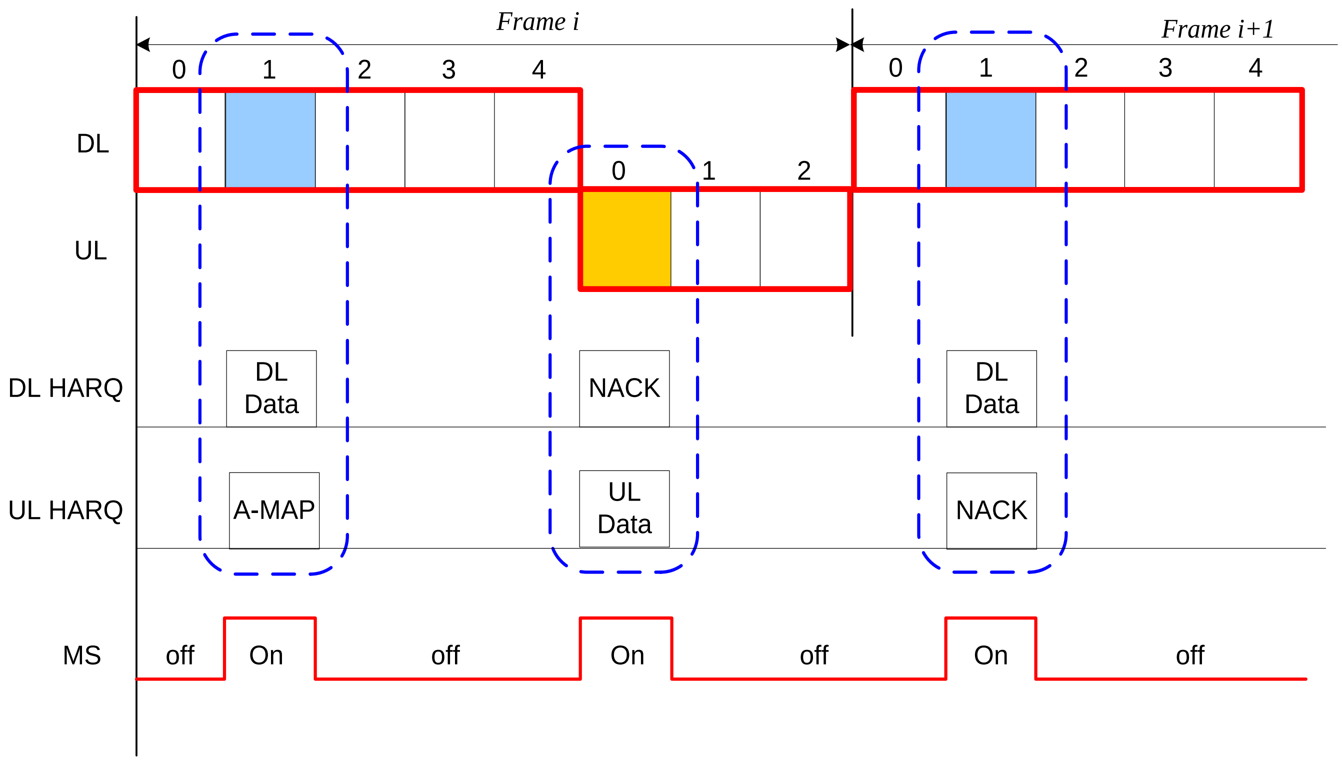
# Periodic HARQ Timing

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



# Synchronize DL and UL Active Cycles

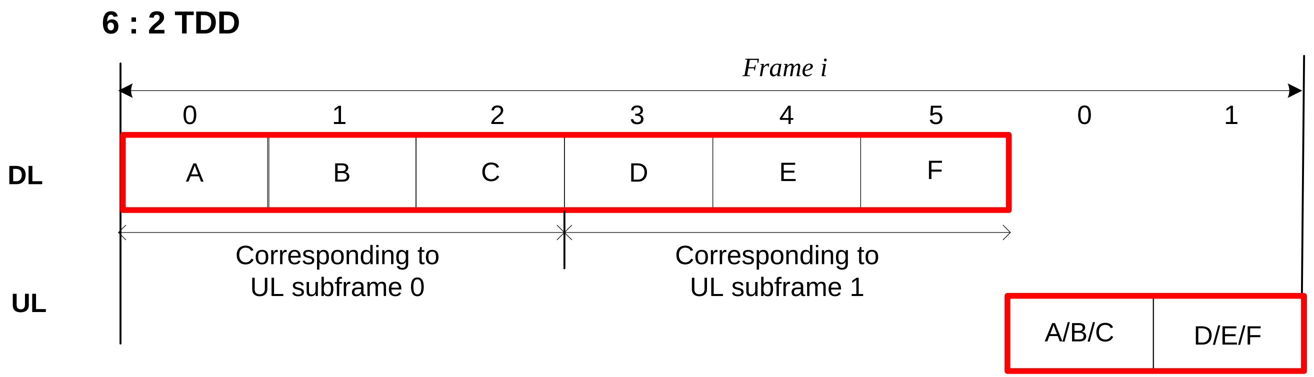
- Maximize Power Saving at MS
  - Same association of subframe for DL and UL HARQ operations
    ⇒ Synchronize DL and UL active cycles

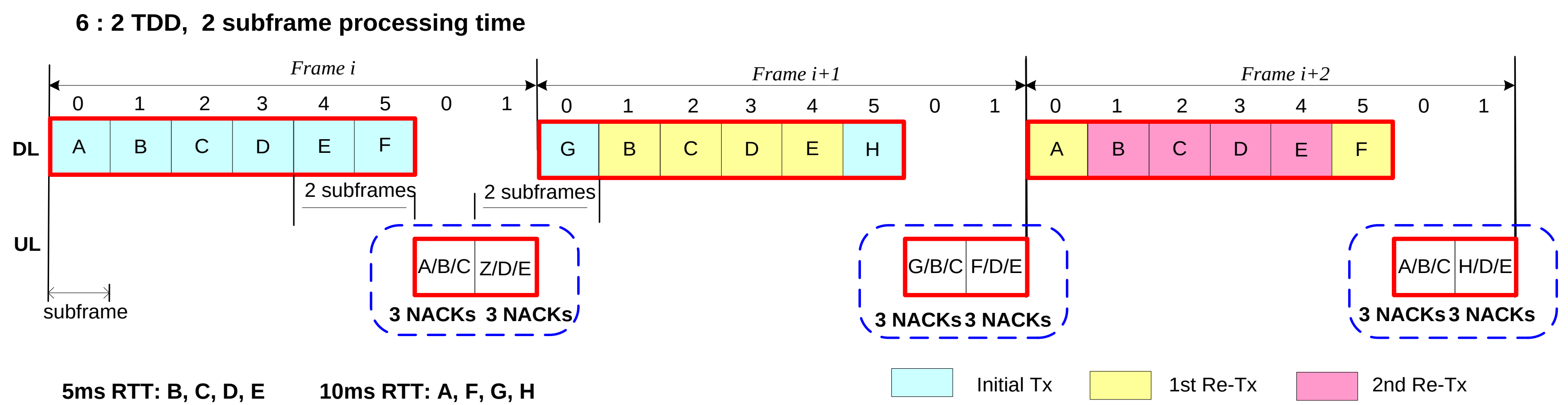



Note: MS is active only in DL subframe #1 and UL subframe #0; 1/4 activity

# 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



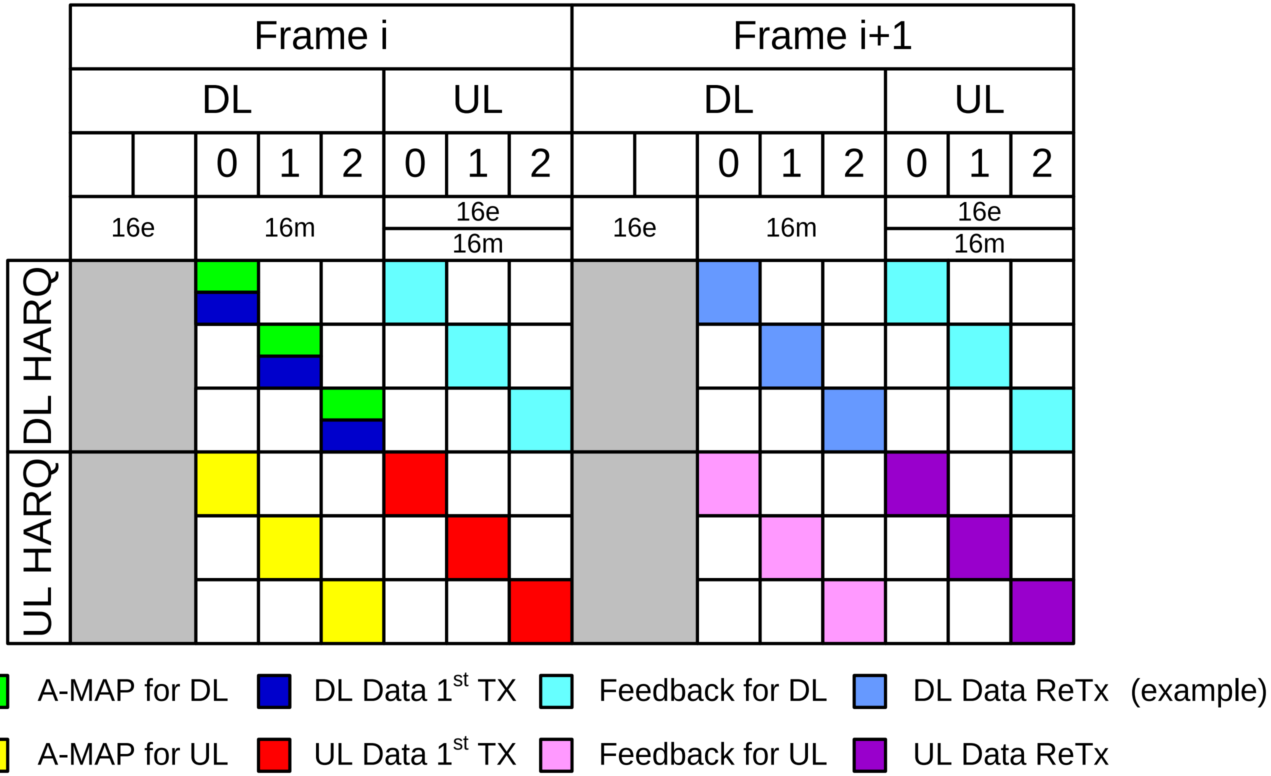
# *Appendix: HARQ timing illustration for …*

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)

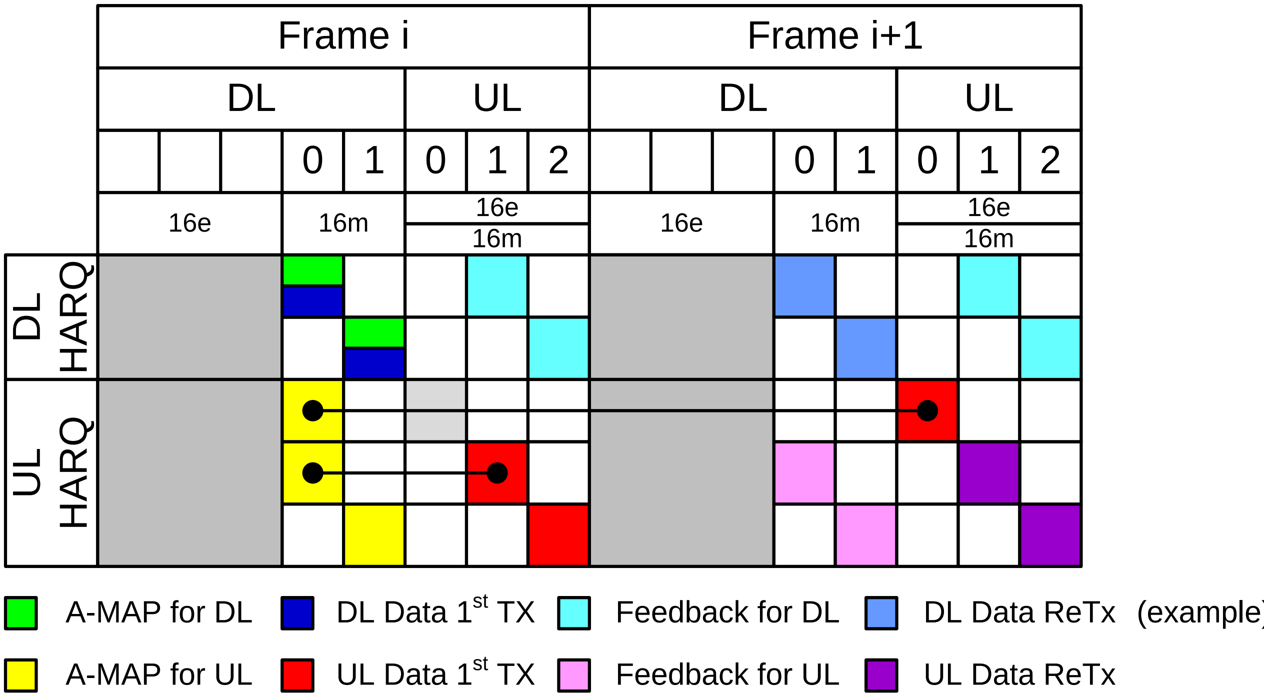
  ⇒ D:U = 3:3 at 16m  (the same equation applied)



# Legacy Support – TDD 5:3 (2/2)

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

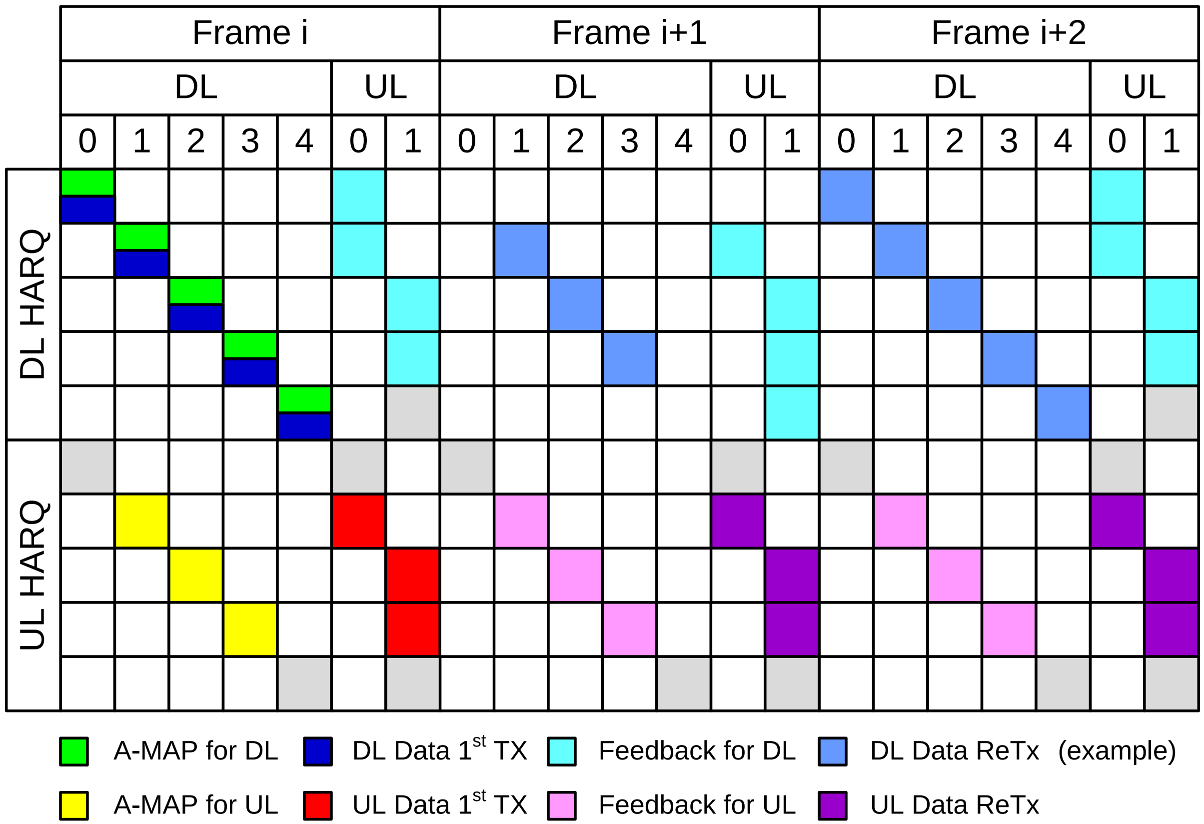
⇒ D:U = 2:3 at 16m (the same equation applied)




- 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)

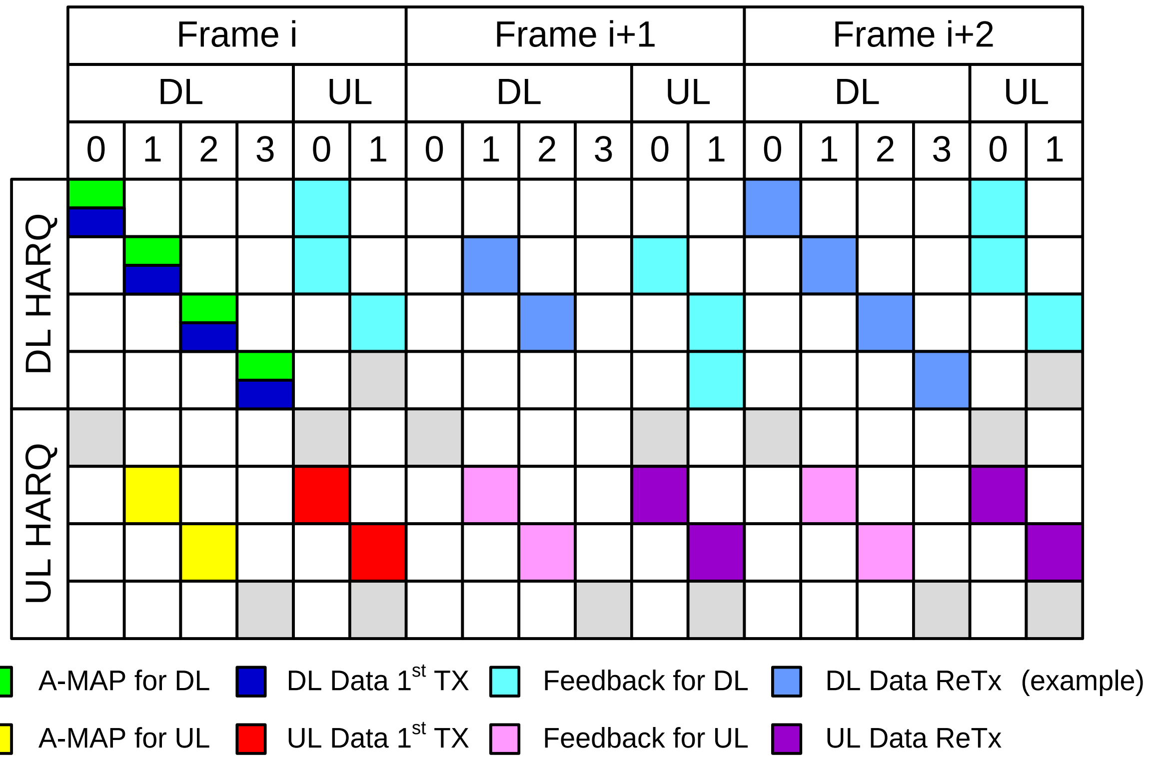
- The same equation applied




- 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)

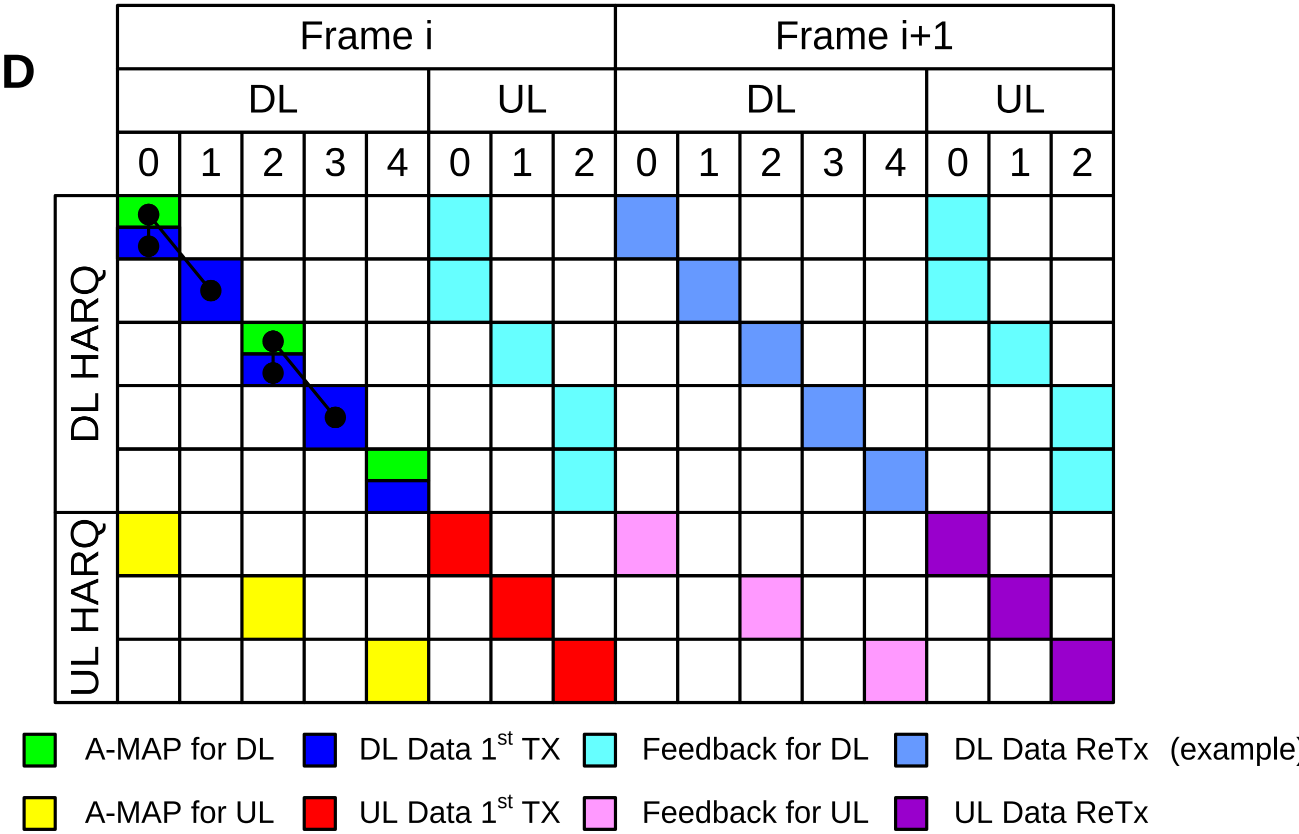
- The same equation applied




- 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,

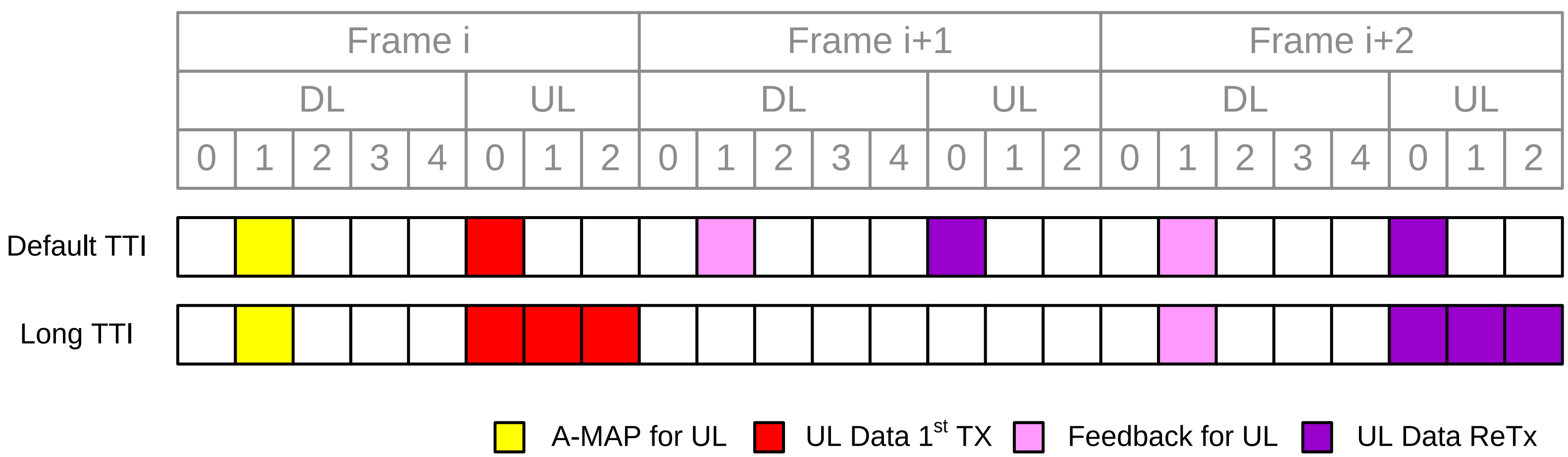
  DL: a slow interlace is applied to subframe DL4

  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)

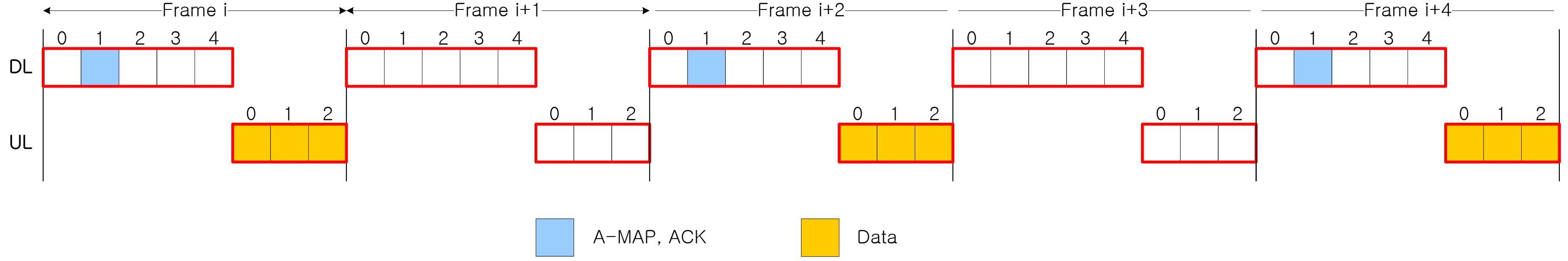
- Example of HARQ timing for a UL long TTI Tx



# Periodic HARQ Timing for Long TTI Tx

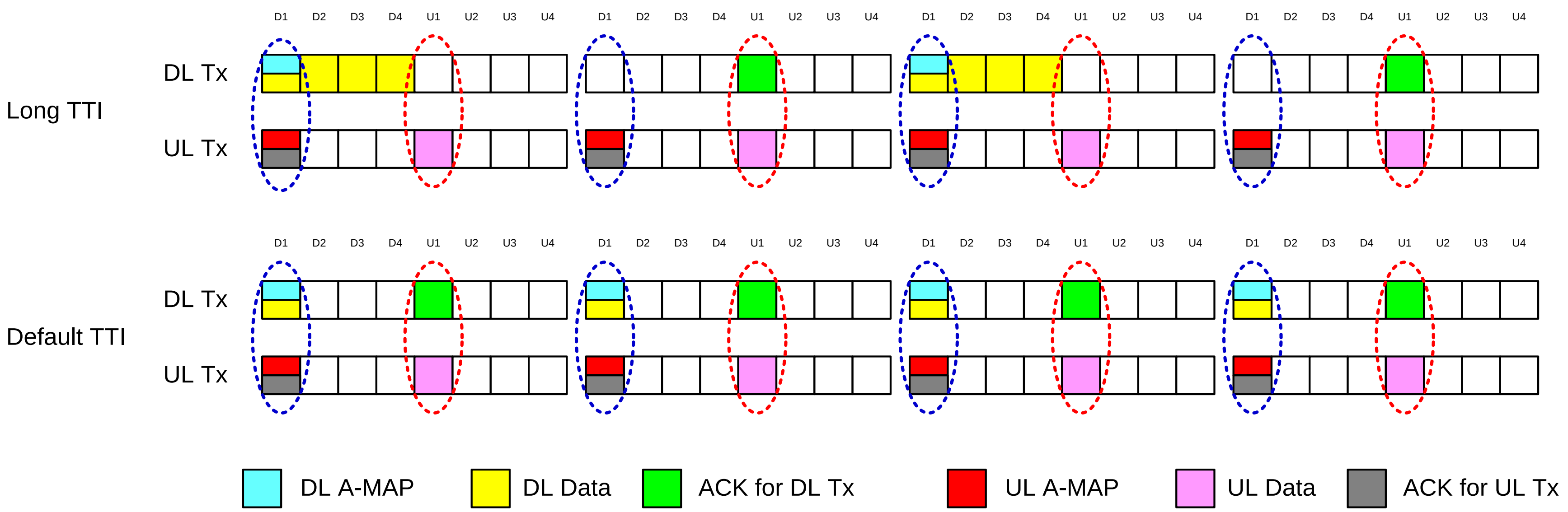
- Even for the long TTI Tx, A periodic Rx/Tx (duty cycle) is provided
  - **Benefit to Power Saving and CLC support**

- 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

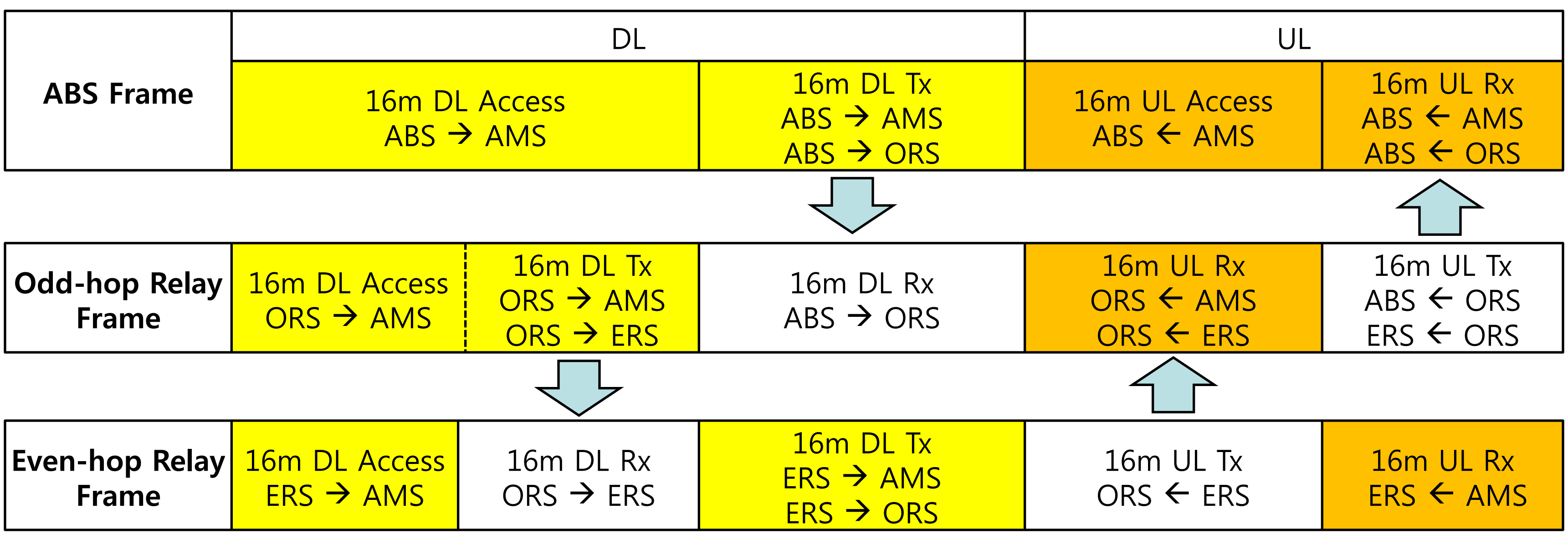
- Benefit to Power Saving and CLC
- Regardless of DL data TTI, the same UL subframe for DL HARQ ACK
  - ⇒ *Maximize power saving and Keep the same CLC pattern in UL*
- At the same time, DL A-MAP and UL A-MAP in the same DL subframe
  - ⇒ *Keep the same micro-sleep pattern in DL (only to monitor one DL 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<br>ORS → AMS | | | 16m DL Rx<br>BS → ORS | 16m UL Access<br>ORS ← AMS | | 16m UL Rx<br>RS(BS) ← ORS | |
| subframe index | 0 | 1 | 2 | | 0 | 1 | | |

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

A-MAP/ DL Data/ DL ACK    UL ACK/ UL Data

| frame index | *i* | | | | | | | | *i+1* | | | | | | | | *i+2* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DL | | | | UL | | | | DL | | | | UL | | | | DL | | | | UL | | | |
| subframe index | 0 | 1 | 2 | | 0 | 1 | | | 0 | 1 | 2 | | 0 | 1 | | | 0 | 1 | 2 | | 0 | 1 | | |
| 3 : 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |

- 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)

A-MAP/ DL Data/ DL ACK    UL ACK/ UL Data

| frame index | *i* | | | | | | | | *i+1* | | | | | | | | *i+2* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DL | | | | UL | | | | DL | | | | UL | | | | DL | | | | UL | | | |
| subframe index | 0 | | | 1 | | | 0 | 1 | 0 | | | 1 | | | 0 | 1 | 0 | | | 1 | | | 0 | 1 |
| 2 : 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |