教育部「5G行動寬頻人才培育跨校教學聯盟計畫」
5G行動網路協定與核網技術聯盟中心

課程: 5G系統層模擬技術

第十三週：通道狀態相依排程演算法與HARQ

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- 13.2.4 PHY Abstraction for HARQ

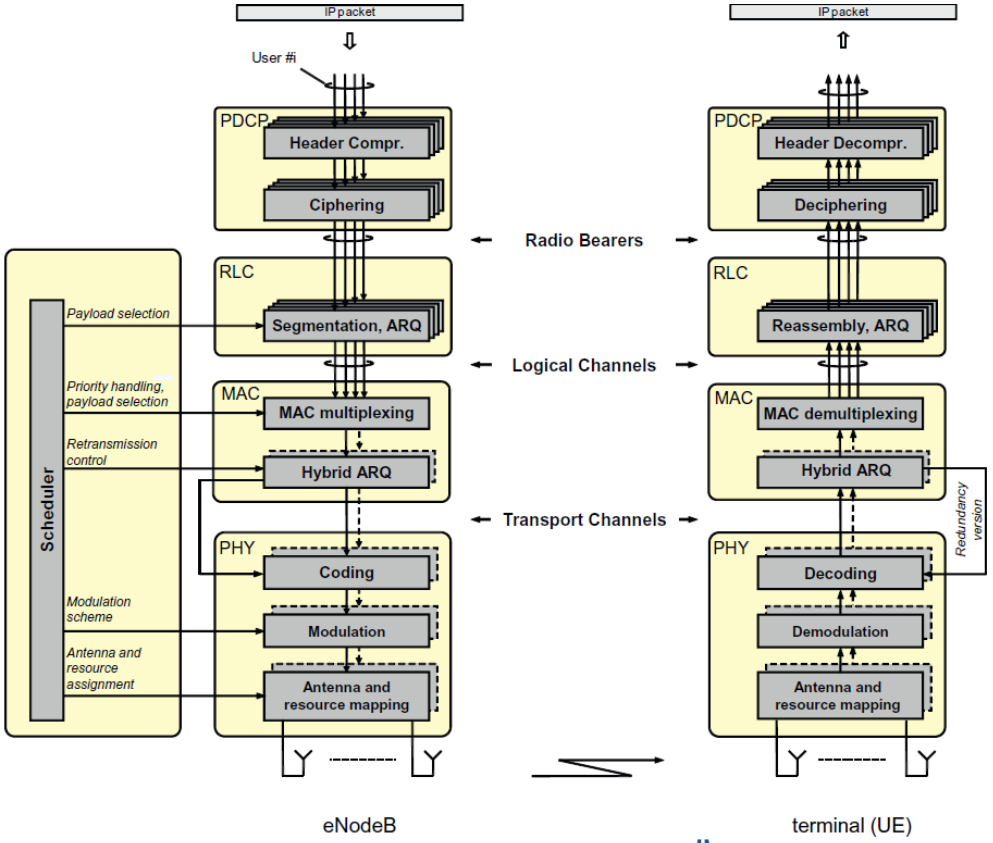
Outline

13.1 排程(Scheduling)(1/3)

- Basic Scheduler Operation
  - MAC in gNB includes dynamic resource schedulers that allocate physical layer resources.
  - The scheduler should take account of the traffic volume and the QoS requirements of each UE and associated radio bearers, when sharing resources between UEs.
  - Schedulers may assign resources taking account the radio conditions at the UE identified through measurements made at the gNB and/or reported by the UE.

13.1 排程(Scheduling)(2/3)

- LTE protocol architecture (DL)



[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 4G LTE/LTE-Advanced for Mobile Broadband_2011
FIGURE 8.4 LTE protocol architecture (downlink).

13.1 排程(Scheduling)(3/3)
Uplink UE Power Control

- The setting of the UE Transmit power for Physical Uplink Shared Channel(PUSCH) transmission is defined as follow.
- If UE transits PUSCH without a simultaneous PUCCH for the serving cell *c*, then the UE transmit power $P_{PUSCH,c}(i)$ for PUSCH transmission in sub frame/slot/sub slot *i* for the serving cell *c* is given by

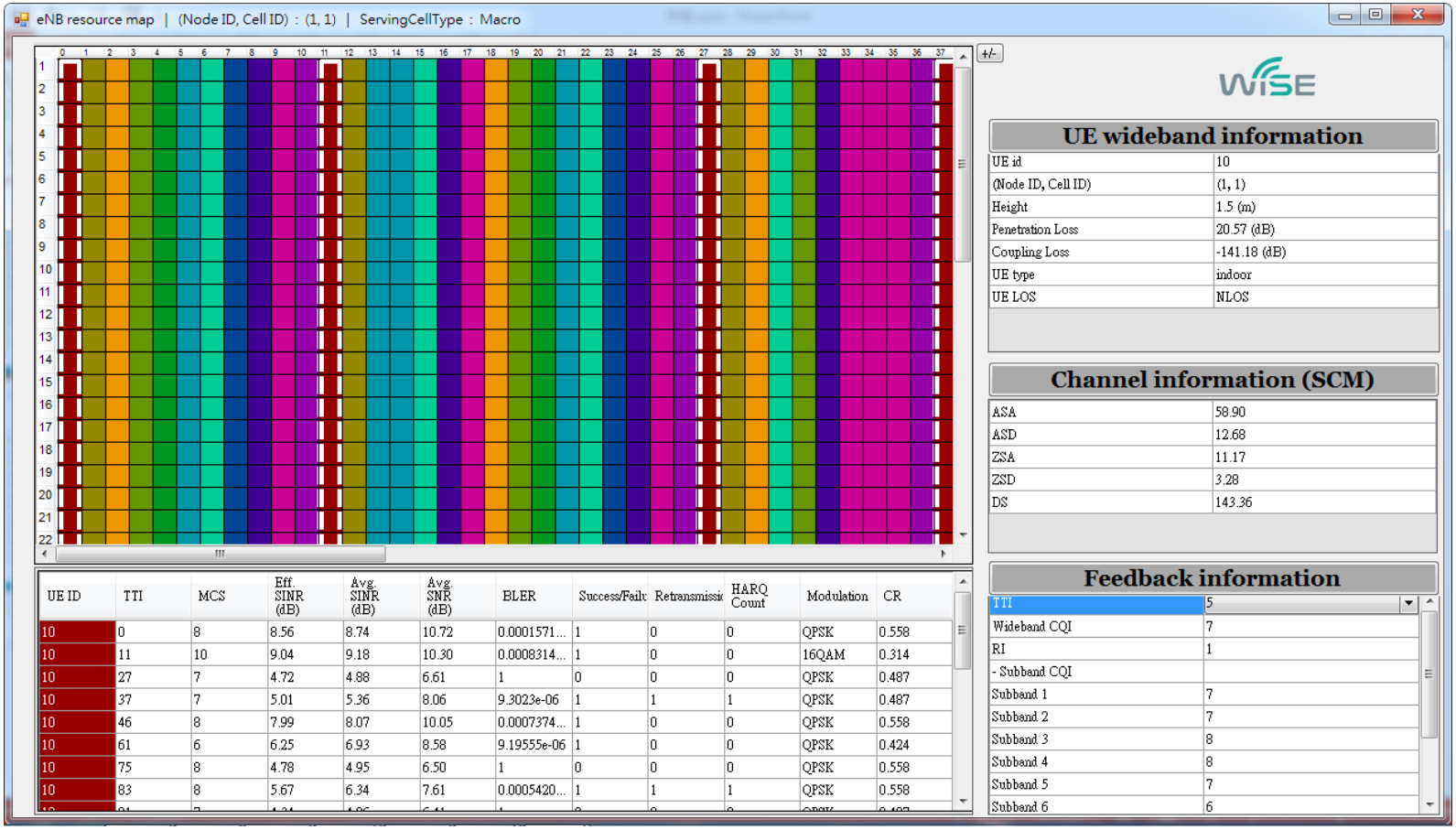
$$P_{\mathrm{PUSCH,c}}(i) = \min\begin{Bmatrix} P_{\mathrm{CMAX},c}(i), \\ 10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i) \end{Bmatrix} \quad [\mathrm{dBm}]$$

[2] 3GPP TS36.213 5.1.1.1

13.1.1 Round-robin Scheduling(1/2)

- Round-robin (RR) is one of the algorithms employed by process and network schedulers in computing.
- As the term is generally used, time slices (also known as time quanta) are assigned to each process in equal portions and in circular order, handling all processes without priority (also known as cyclic executive).
- Round-robin scheduling is simple, easy to implement, and starvation-free.
- Round-robin scheduling can also be applied to other scheduling problems, such as data packet scheduling in computer networks.
- **Round-robin scheduling uses equal bandwidth for all UEs without accounting for channel conditions.**

13.1.1 Round-robin Scheduling(2/2)



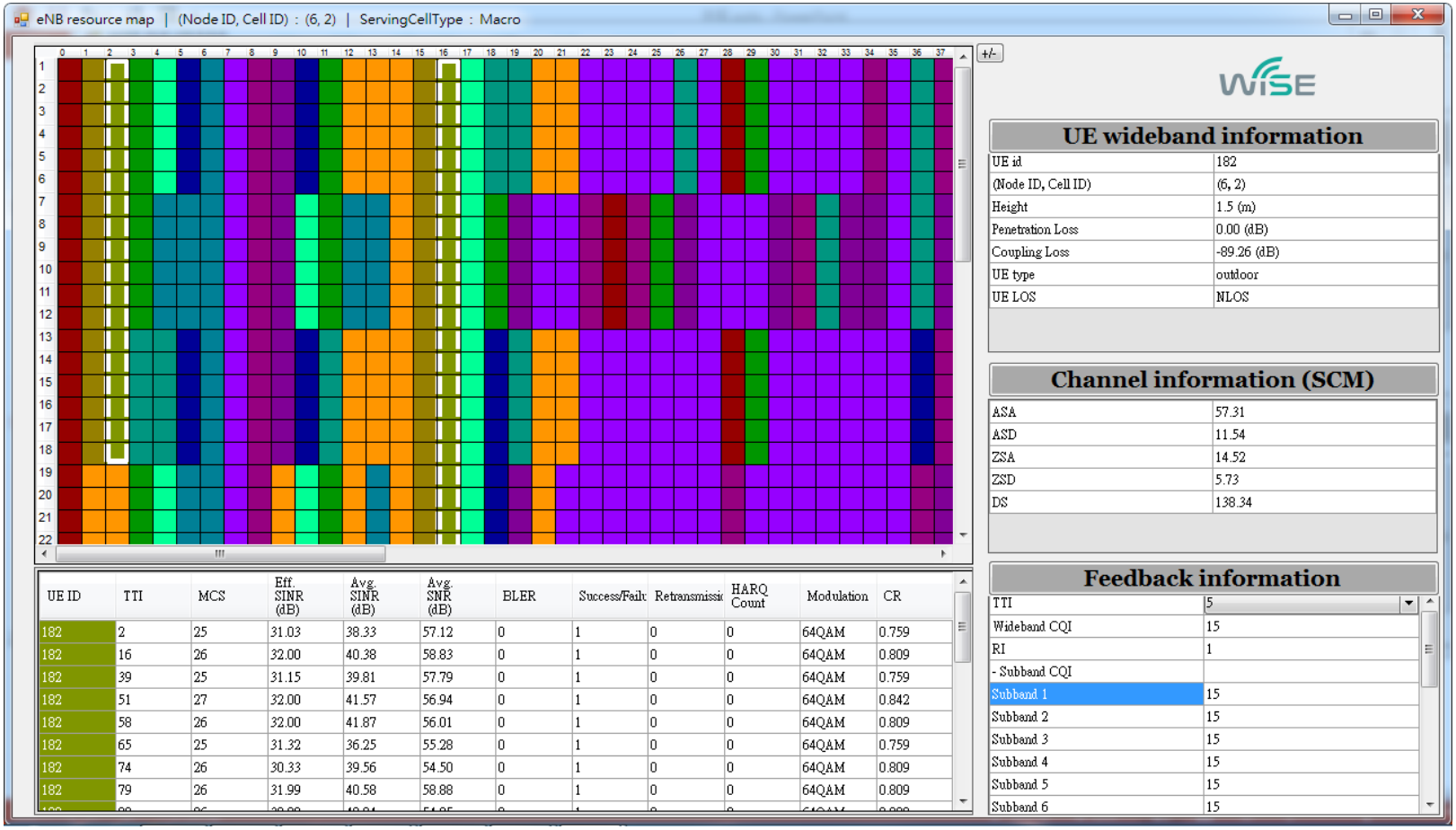
13.1.2 Proportional Fairness Scheduling

- Proportional Fairness tries to balance between the QoS priorities and total throughput.
- Schedule the channel for the station that has the maximum of the priority function:

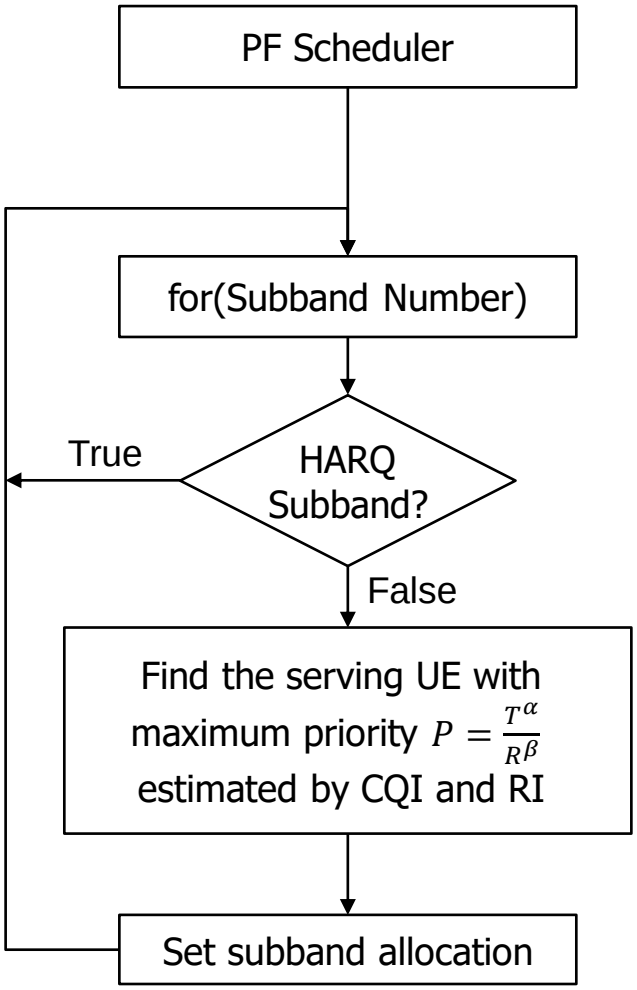
$$P = \frac{T^{\alpha}}{R^{\beta}}$$

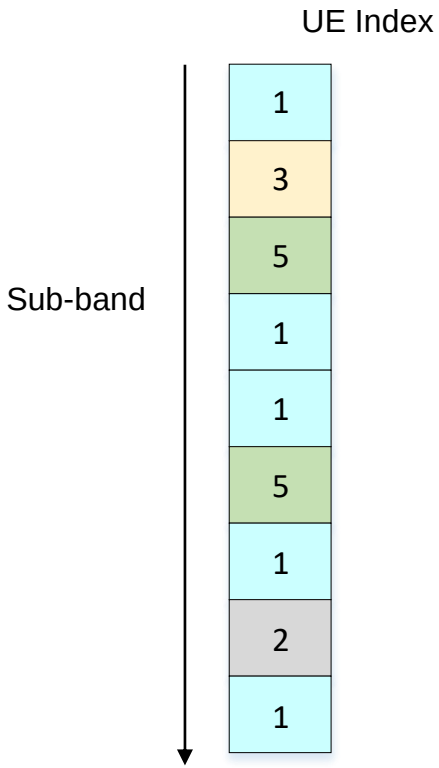
  - T denotes the data rate potentially achievable for the station in the present time slot.
  - R is the historical average data rate of this station.
  - α and β tune the "fairness" of the scheduler.

13.1.2 Proportional Fairness Scheduling(Subband)(1/2)



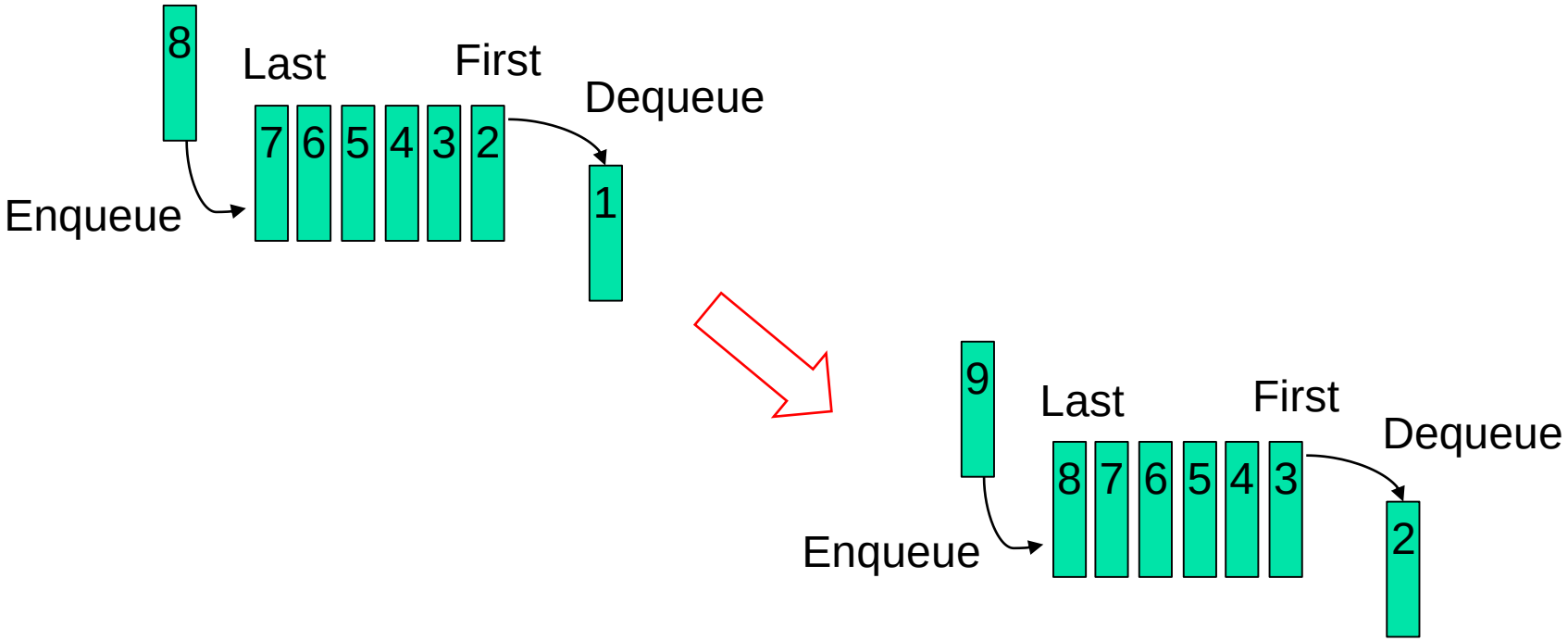
13.1.2 Proportional Fairness Scheduling(Subband)(2/2)





13.1.3 First In First Out

- First In First Out (FIFO): queues processes in the order that they arrive in the ready queue.



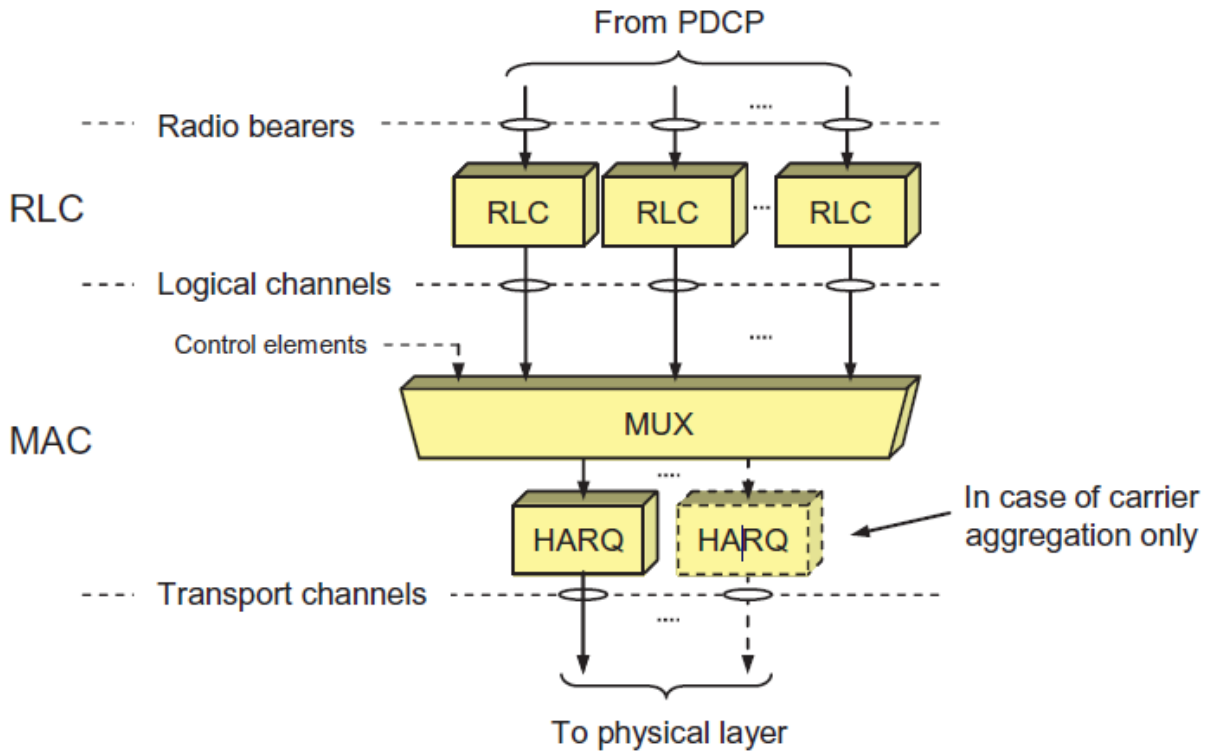
Outline

13.2 HARQ

- ARQ(Automatic Repeat Request) and HARQ(Hybrid ARQ)
  - E-UTRAN(Evolved Universal Terrestrial Radio Access Network) provides ARQ and HARQ functionalities.
  - The ARQ functionality provides error correction by retransmissions in acknowledged mode at Layer 2.
  - The HARQ functionality ensures delivery between peer entities at Layer 1.

13.2.1 HARQ 介紹(1/3)

- The HARQ protocol part is present in both the transmitting and receiving ends of the MAC protocol.



[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 4G LTE/LTE-Advanced for Mobile Broadband_2011
FIGURE 12.1 RLC and hybrid-ARQ retransmission mechanisms in LTE.

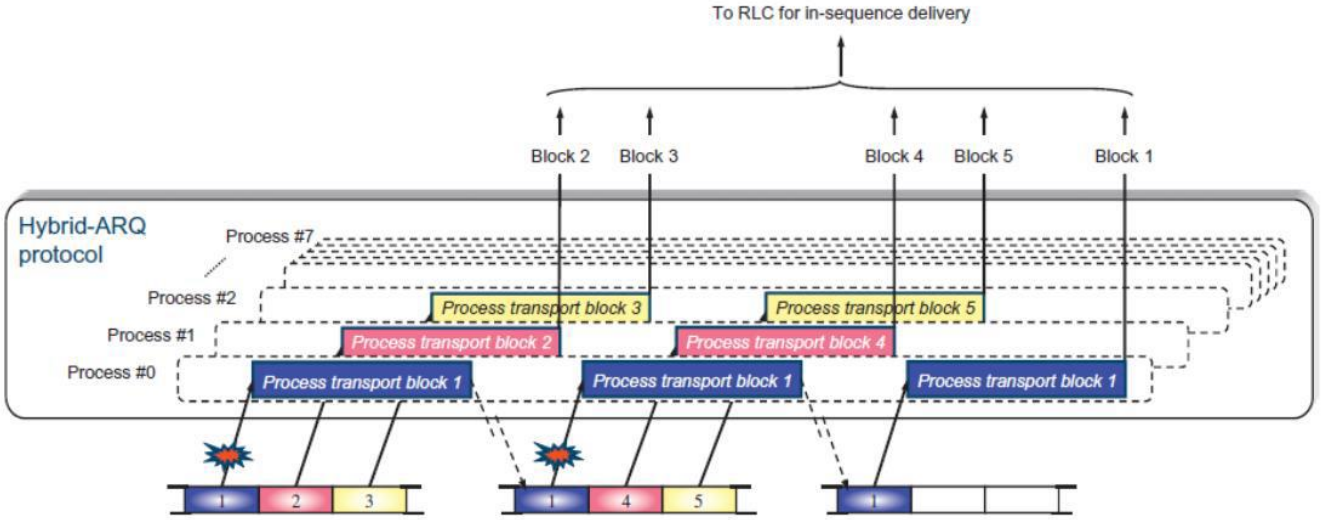
13.2.1 HARQ 介紹(2/3)

- The HARQ within the MAC sublayer has the following characteristics:
  - HARQ transmits and retransmits transport blocks
  - In the downlink
    - *N*-process Stop-And-Wait
    - Asynchronous adaptive HARQ
    - Uplink ACK/NAKs in response to downlink (re)transmissions are sent on PUCCH or PUSCH
      - For DL UEs or UEs in enhanced coverage, uplink ACK/NAKs are sent in response to transmission bundles
    - PDCCH, MPDCCH or NPDCCH signals the HARQ process identifier and if it is a transmission or retransmission
    - Retransmissions are always scheduled through PDCCH, MPDCCH or NPDCCH

13.2.1 HARQ 介紹(3/3)

- Synchronous for UL
  - Uses the specific process in a specific subframe. Every 8 subframes UE repeats the process id. As a result, eNB knows exactly when each HARQ process comes.
  - UL HARQ Process ID = (SFN x 10 + subframe) modulo 8
- Asynchronous for DL
  - Network sends these (Process ID, RV) in PDCCH DCI0 message. UE doesn't know which Process ID to look for until it gets the DL data.
- Adaptive retransmission
  - MCS and RB's may change as per resources allocated by the eNB on PDCCH DCI0 transmission
  - UE does "Adaptive retransmission" if it detects PDCCH(DCI 0 and NDI not-toggled). UE does not care about HARQ feedback (PHICH), it just retransmits based on DCI 0 information
- Non-Adaptive retransmission
  - Retx occurs only in predefined time after previous tx/retx using the same resources
  - Advantage is only NAK has to be signaled back to start a retx
  - UE figures out that it is using "Non-Adaptive retransmission" if it got "HARQ feedback (PHICH=NACK)" but does not get DCI 0 over PDCCH and instead uses predefined sequence.

For example



[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 4G LTE/LTE-Advanced for Mobile Broadband_2011
FIGURE 12.2 Multiple parallel hybrid-ARQ processes forming one hybrid-ARQ entity

13.2.2 Hybrid ARQ with Soft Combining(1/2)

- Hybrid ARQ with soft combining provides robustness against transmission errors
- Hybrid-ARQ protocol is part of the MAC layer, while the actual soft combining is handled by the physical layer
- Hybrid ARQ is not applicable for all types of traffic
  - Hybrid ARQ is only supported for the DL-SCH and the UL-SCH
- LTE hybrid-ARQ protocol uses multiple parallel stop-and-wait processes

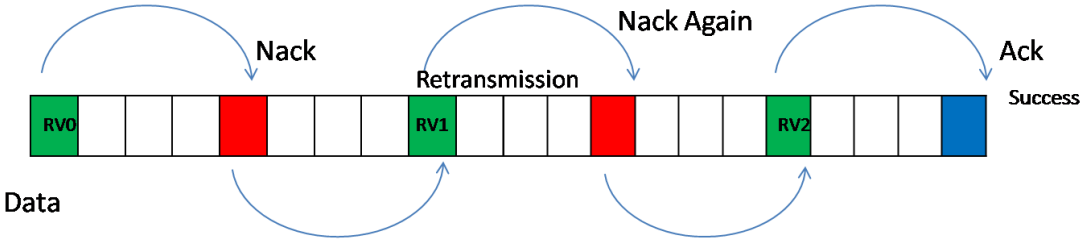
13.2.2 Hybrid ARQ with Soft Combining(2/2)

- The receiver informs the transmitter through a single acknowledgement bit indicating whether the decoding was successful
- The receiver must know to which hybrid-ARQ process a received acknowledgement is associated
- ACK/NACK is sent 4 sub-frames after the packet is received in the FDD system
- The hybrid-ARQ retransmissions are handled independently per component carrier
- Downlink retransmissions may occur at any time after the initial transmission
  - The protocol is asynchronous – and an explicit hybrid-ARQ process number is used to indicate which process is being addressed
- The hybrid-ARQ mechanism can rapidly correct transmission errors.

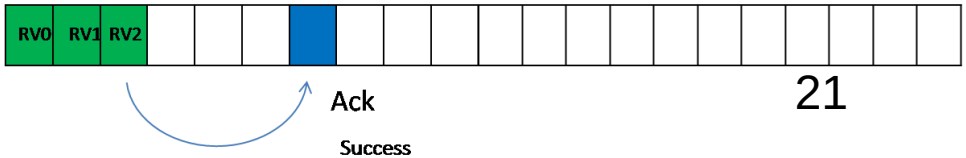
For example

- HARQ is a process where receiver combines the new transmission every time with previous erroneous data. There is one drawback however, that it can result in delay and too much control overhead in case of poor radio conditions if the sender has to attempt many transmissions. For services like VoIP this means bad end user experience. Well, there is another way- Instead of re-transmitting the erroneous data with new set of coded bits, why not send few versions (redundancy versions) of the same set of bits in consecutive TTI and eNB sends back Ack when it successfully decodes the bits.

Normal HARQ in LTE

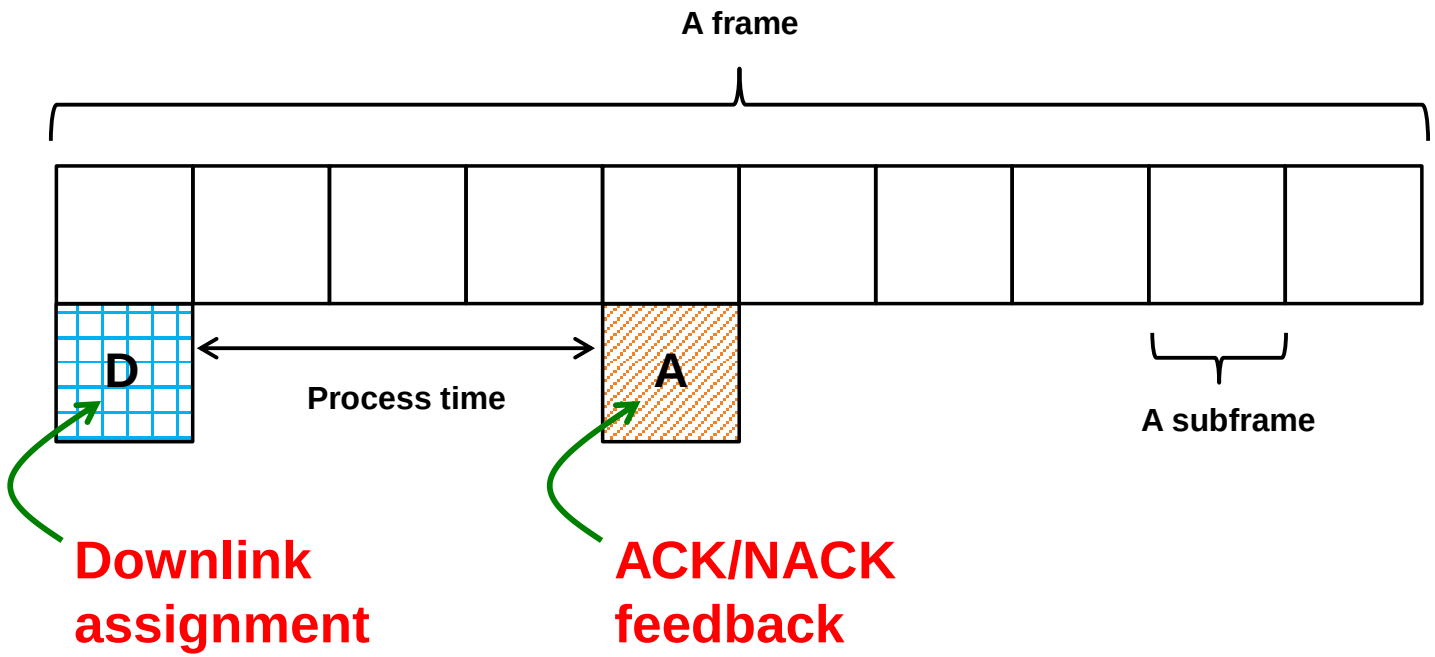


HARQ with TTI Bundling



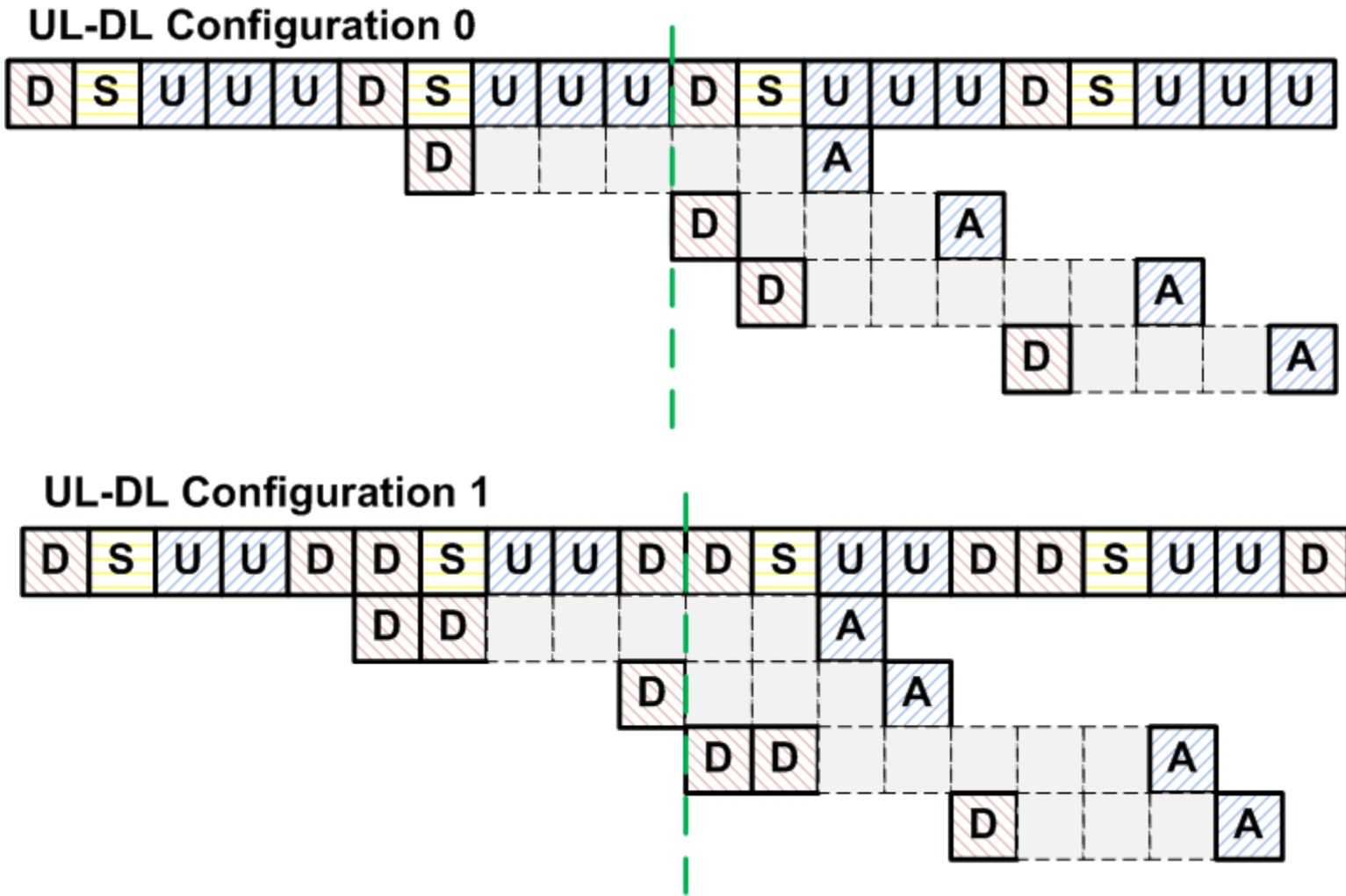
13.2.3 HARQ Process(1/5)

- FDD HARQ Process

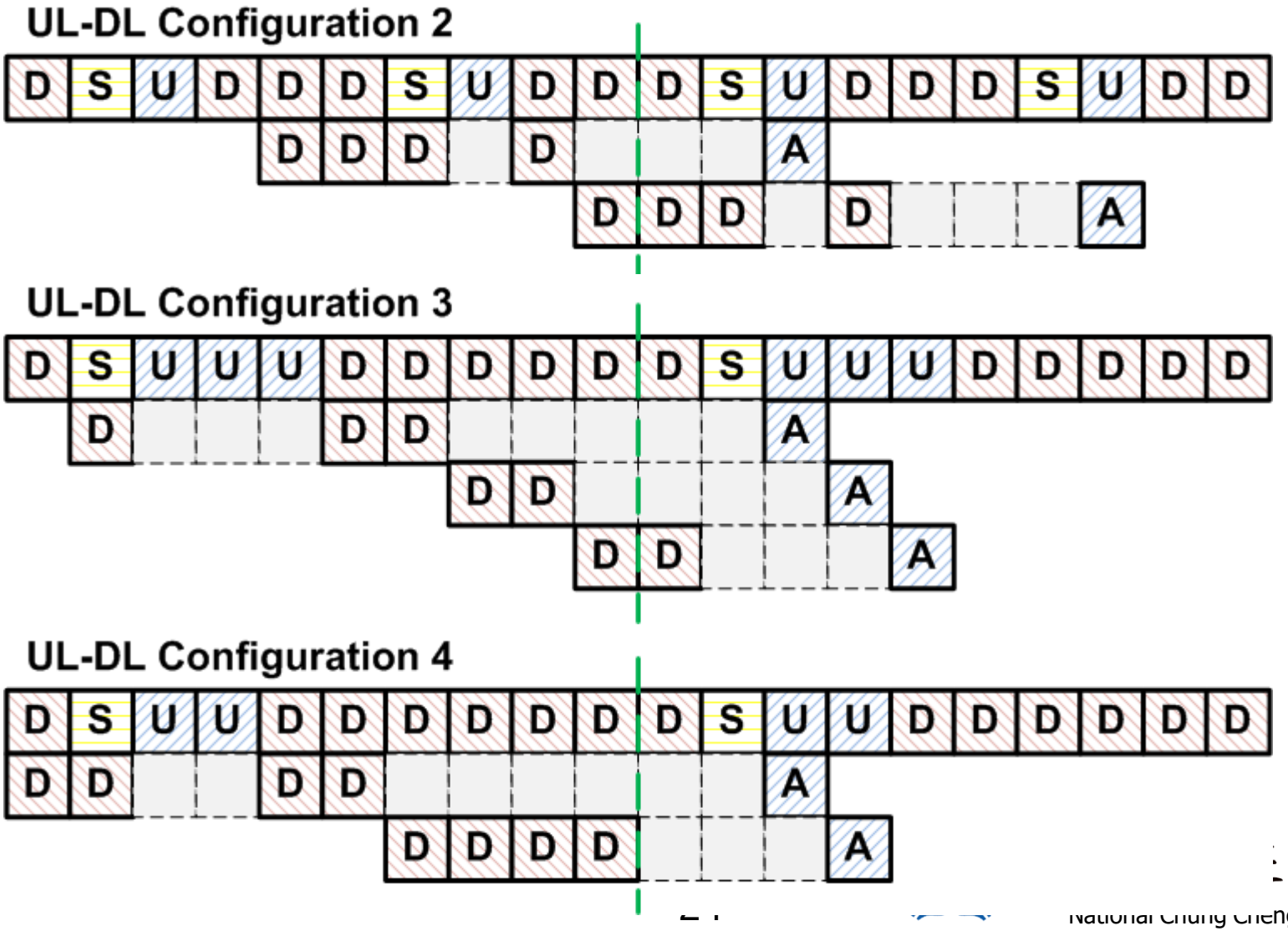


13.2.3 HARQ Process(2/5)

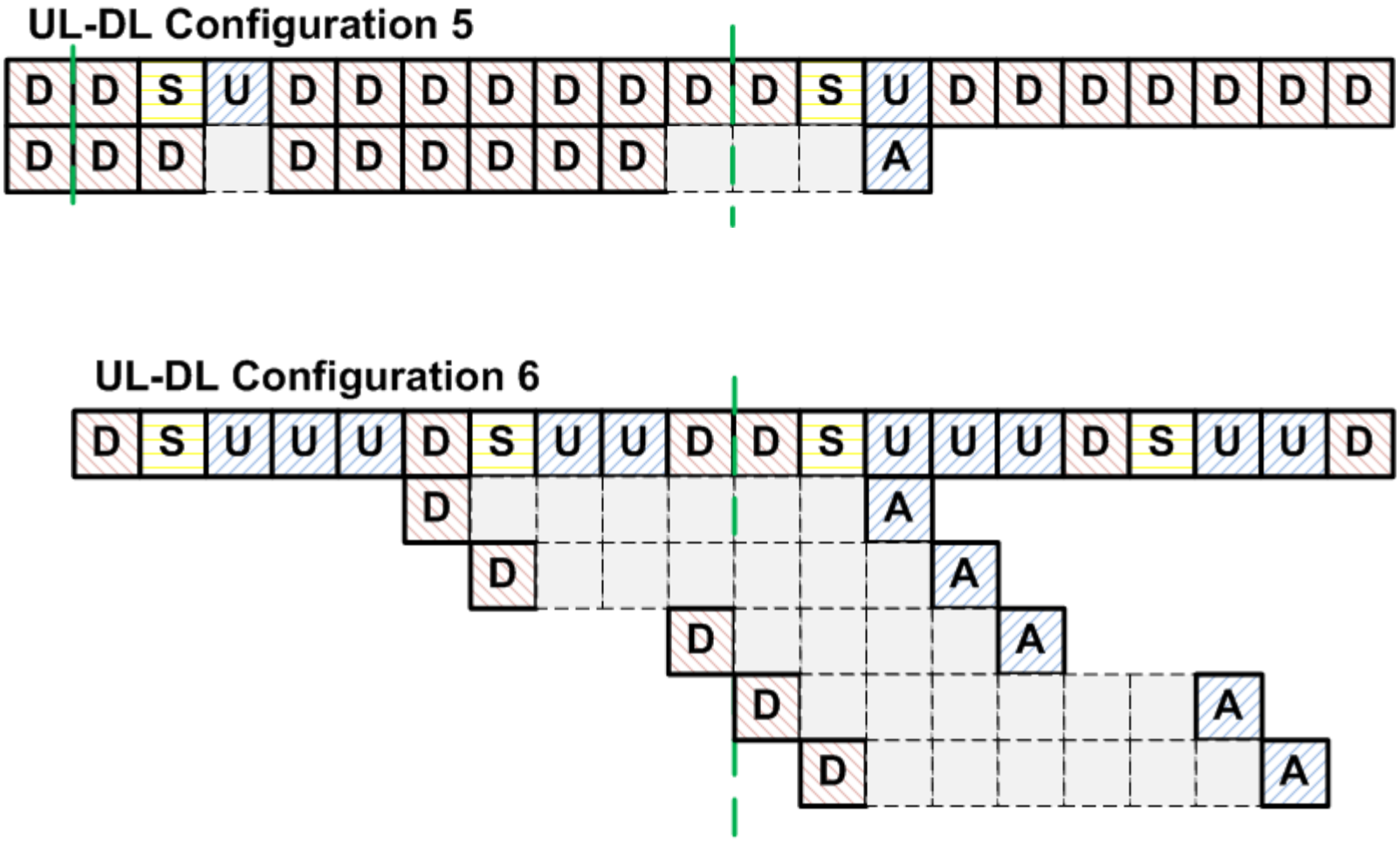
- DL HARQ Process



13.2.3 HARQ Process(3/5)

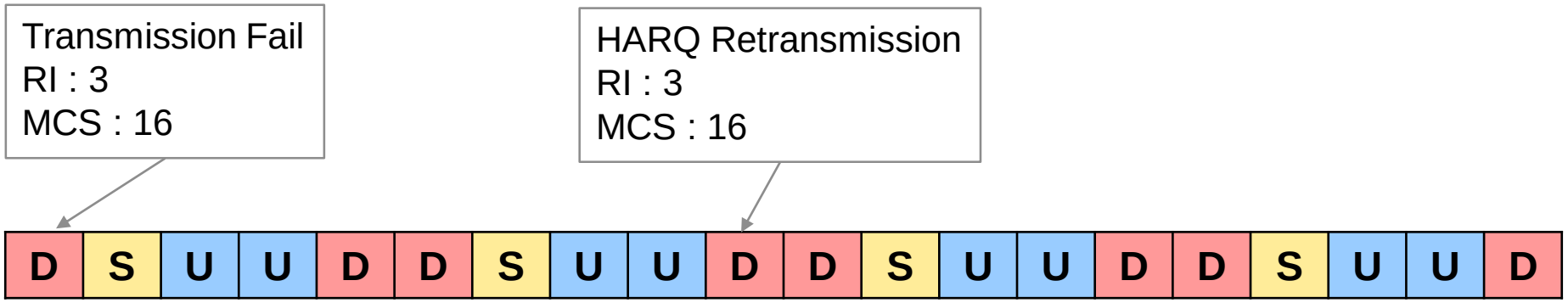


13.2.3 HARQ Process(4/5)



13.2.3 HARQ Process(5/5)

- Note that the HARQ retransmission's RI and MCS relay on the initial transmission not CSI feedback.



PHY Abstraction for HARQ

- According to [3]IEEE 802.16m Evaluation Methodology Document (EMD)
- The following abstraction is proposed as baseline:
  - For Chase combining (CC): The SINR values of the corresponding sub-carriers are summed across retransmissions, and these combined SINR values will be fed into the PHY abstraction.
  - For Incremental redundancy (IR): The transmission and retransmissions are regarded as a single codeword, and all the SINR values are fed into the PHY abstraction. In practice, some partial repetition occurs, when part of the coded information is repeated in subsequent retransmissions.
- For methods combining CC and IR the second approach is preferred but should be justified by link level simulations.

For Example

- The effective SINR for EESM in the case of Chase Combining is given by

$$\gamma_{eff} = -\beta \ln\left(\frac{1}{N}\sum_{n=1}^{N}\exp\left(-\frac{\sum_{j=1}^{q}\gamma_{nj}}{\beta}\right)\right)$$

- where γ_{eff} is the effective SINR after q transmissions that is input to the AWGN reference to compute the BLER, and γ_{nj} is the n-th symbol SINR during j-th retransmission.

參考資料

[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld, 4G LTE/LTE-Advanced for Mobile Broadband_2011

[2] 3GPP TS 36.213 V15.6.0 (2019-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures(Release 15)

[3]IEEE 802.16m Evaluation Methodology Document (EMD),July 2008