# Flexible Frame Structures for TDD and Relay Operations

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Shu Wang, Ki-Dong Lee, Li-Hsiang Sun, Sang G. Kim, E-mail: swang@lge.com
LG Electronics Mobile Research, San Diego

Re: TGm Call for Contributions, IEEE 802.16m-07/047, specifically on "16m Frame Structure with special attention to legacy support"

Abstract:
Discussion on the 16m frame structure supporting coexistence between legacy and advanced mobiles. One frame structure framework and several frame structure examples are proposed with brief calculations of latency.

Purpose:
To discuss the frame structure in the 802.16m SDD

# Outline

- Key Considerations for frame structure design
  - Relationship between frame structure pattern and upper layer service requirement,
  - Backward compatibility between legacy and 16m systems,
  - Interference due to downlink/uplink switching point unalignment,
  - Harmonization opportunities
- A flexible frame structure framework.
  - It essentially comprises of three zones: 1) downlink zone, 2) flexible zone, and 3) uplink zone
- Configuration examples of the proposed frame structure framework.
  - DDU or DUU mode
  - DDUU mode
  - DUDU mode

# Key Considerations for Frame Structure (FS) Design from SRD.

- 802.16m System Requirements on
  - “Coexistence” between legacy and 16m: §5.1 Legacy Support
  - Reduced (improved) “latency”: §6.2.1 Data Latency
  - Improved “sector throughput”: this is affected by various things other than FS design but basically a given FS can bound the performance
  - …

# Service Varieties Demand A Flexible Frame Structure (1/2)

- Different services may have their own requirements on the necessary data rate range, acknowledge delay, downlink/uplink ratio, etc.
- Even for the same class of services, they may have different QoSs.
- For example, Scalable Video Coding (SVC): extensions of H.264/MPEG-4 AVC. For example,
  - Baseline Profile (BP): Primarily for lower-cost applications with limited computing resources, such as videoconferencing and mobile applications.
  - Main Profile (MP): Originally intended as the mainstream consumer profile for broadcast and storage applications.

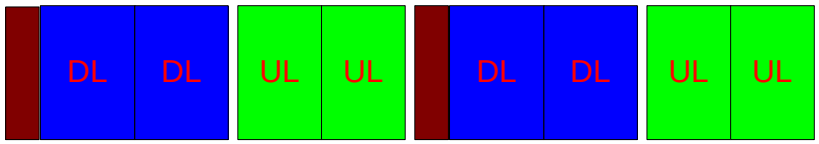
| Class | Abbreviation | Parameters (ranging process) |
|---|---|---|
| **Unsolicited grant service** | **UGS** | tolerated jitter, service data unit (SDU) size (in case of fixed length SDU), minimum reserved traffic rate, maximum latency, request/transmission policy, and unsolicited grant interval |
| **Extended real-time variable rate** | **ERT-VR** | maximum latency, tolerated jitter, minimum reserved traffic rate, maximum sustained traffic rate, traffic priority, request/transmission policy, and unsolicited grant interval |
| **Real-time variable rate** | **RT-VR** | maximum latency, minimum reserved traffic rate, maximum sustained traffic rate, traffic priority, request/transmission policy, and unsolicited polling interval |
| **Non-real-time variable rate** | **NRT-VR** | minimum reserved traffic rate, maximum sustained traffic rate, traffic priority, and request/transmission policy |
| **Best effort** | **BE** | maximum sustained traffic rate, traffic priority, and request/transmission policy |

IEEE 802.16e QoSs

| Level | Macroblock / second | Frame size | Baseline profile/ MP / XP | High profile | High 10 profile |
|---|---|---|---|---|---|
| 1 | 1485 | 99 | 64kbps | 80kbps | 192kbps |
| 1.1 | 3000 | 99 | 192kpbs | 240kbps | 576kbps |
| 1.2 | 6000 | 396 | 384kbps | 480kbps | 1152kbps |
| 1.3 | 11880 | 396 | 768kbps | 960kbps | 2304kbps |
| 2 | 11880 | 396 | 2Mbps | 2.5Mbps | 6Mbps |
| 2.1 | 19800 | 792 | 4Mbps | 5Mbps | 12Mbps |

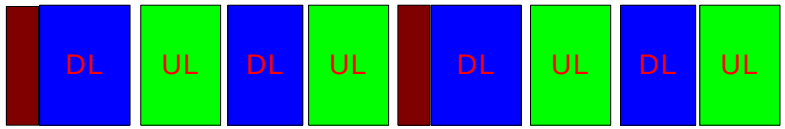
H.264/MPEG-4 AVC Profiles

# Service Varieties Demand A Flexible Frame Structure (2/2)




The DDUU Mode

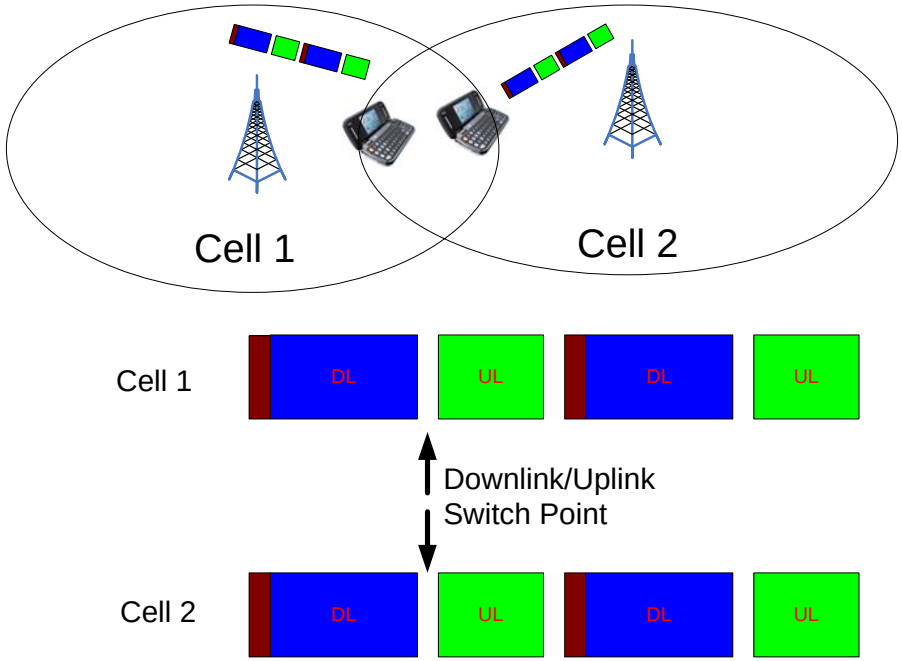
The DUDU Mode



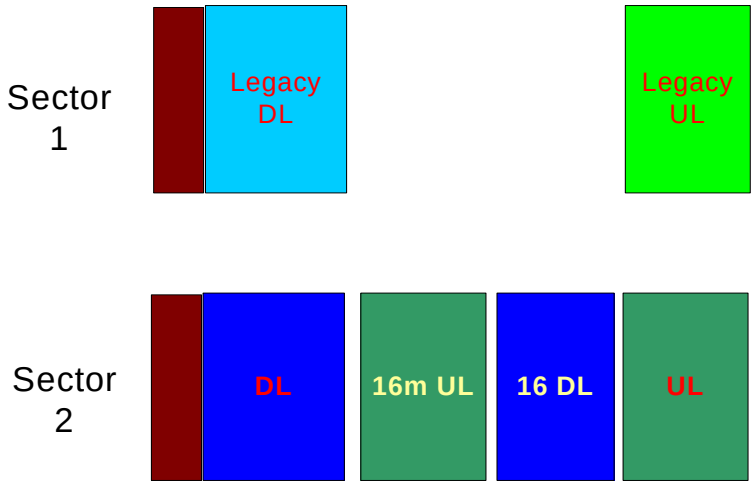

- DDUU has the minimum # of switching points. It may have good achievable throughput if the number of switching point is critical.
- DUDU has better fast ACK opportunities. it may be a good choice for some services, e.g., gaming, which requires fast acknowledges and short delays.
- There are pros and cons of each patter.  It is difficult to say which one is definitely better than the other one.
- The choice of the best frame pattern depend on the requirement of upper layer services. And this can be very dynamic.

# Interference Due to DL/UL Switch Point Unalignment

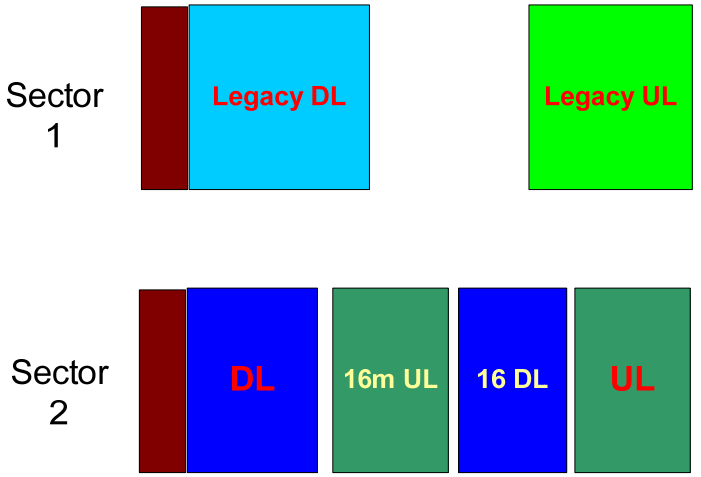
- Inter-cell interference may become more serious, if the DL/UL switching points for the closest cells are unaligned.
- However, this DL/UL unaligned interference may have strong interference on MSs on the cell boundaries, not on the MSs inside the cells.
- A strict limitation on the number of switch points and their position may hurt the achievable network performance.



# Interference Between Legacy and 16m Systems




Conservative transmission with hard limitations on achievable throughputs

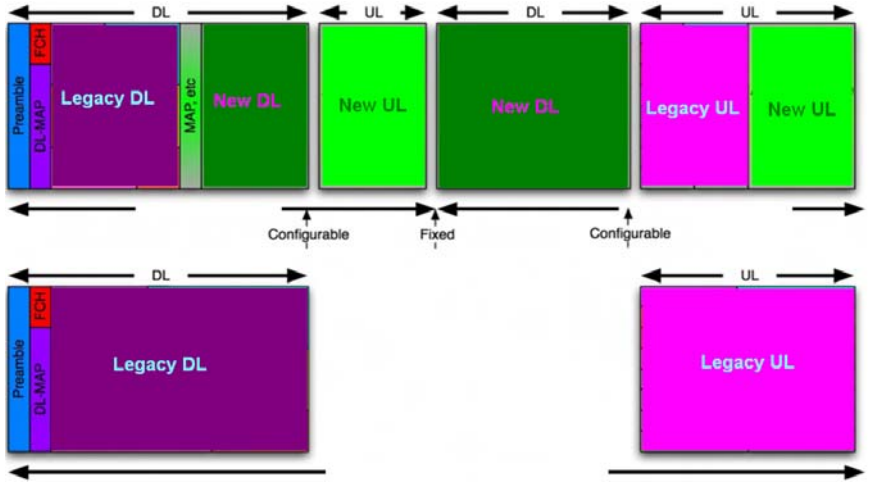



Aggressive transmission with more inter-system interference

- Conservative transmission v.s. aggressive transmission?
  - It depends the number of active users and the services they requested.
  - It also depends on the total interference experienced by each scheduled mobiles, including both legacy and 16m mobiles.
- Keep in mind, this inter-system interference is one of the many interferences received by each mobile, though it can be a very serious one.

# Review of Previous 16m FS Proposals

- Under “Coexistence” conditions,
  - Those proposals intended to improve “latency” at the cost of “reduction in throughput”
  - Having more DL/UL switching points means more RTGs :
    - More breakdowns lead to larger portion of RTGs and TTG, causing the resource utilization to be reduced, even if small
    - Breakdowns may result in wastage of bandwidth in legacy cells



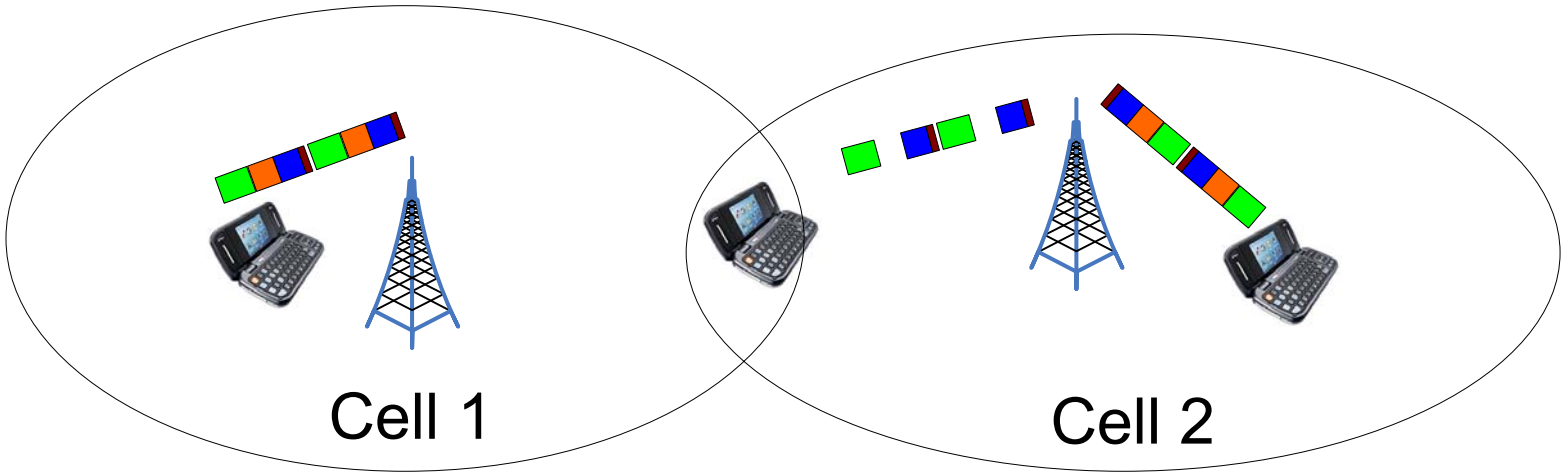

<Source: IEEE C80216m-07_263, NextWave Broadband>

# Scheduler can manage interference (1/2)

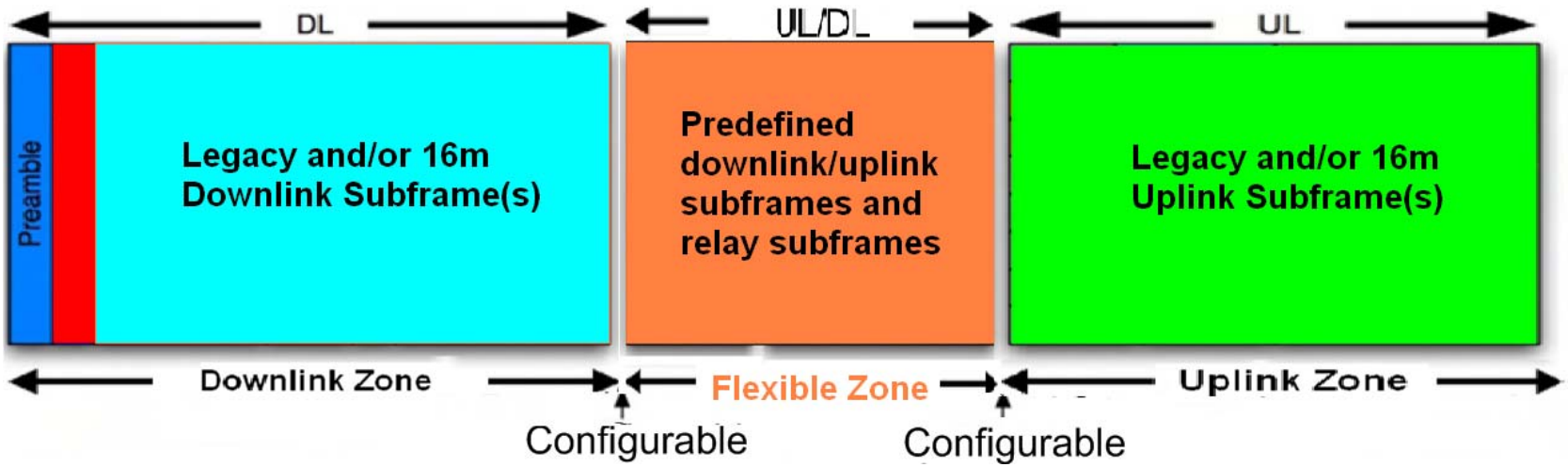
- The performance of 16m and the mixing of 16m/16e will large depends on
  - The flexibility of frame structure design
  - How to manage the interference inside the network
  - Etc.
- Should the frame structure design and the interference management be completely independent to each other?
  - This may generate too much interference and make the scheduler design impossible, when the number of active mobiles is large.
- On the other hand, too many considerations on putting interference avoiding into frame structure design may make limit the combinations for frame structure design.
- A balanced and flexible frame structure design should be interesting.

# Scheduler can manage interference (2/2)

- Additional Thoughts:
  - There is a requirement on reporting of network radio resource.
    - Section 6.4.1 Reporting: “IEEE802.16m shall enable advanced RRM by enabling the collection of …. Etc.”
    - This report mechanism may also be used for helping the scheduler of each base station to cooperatively manage interference.
  - Or the scheduler can try to serve the mobiles inside cells with those subframes in questions.



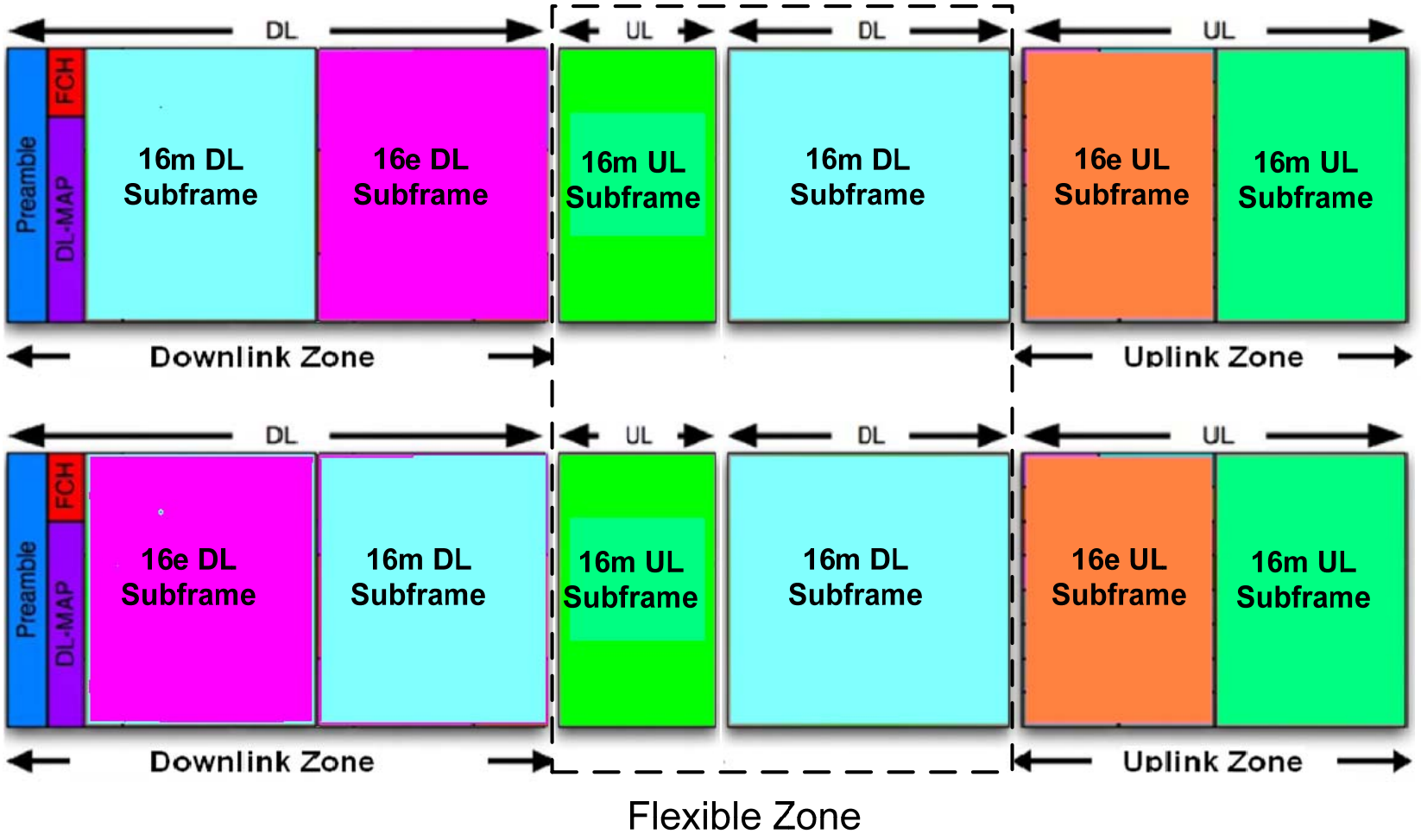
# Our Frame Structure Proposal (1/2)



# Our Frame Structure Proposal (2/2)

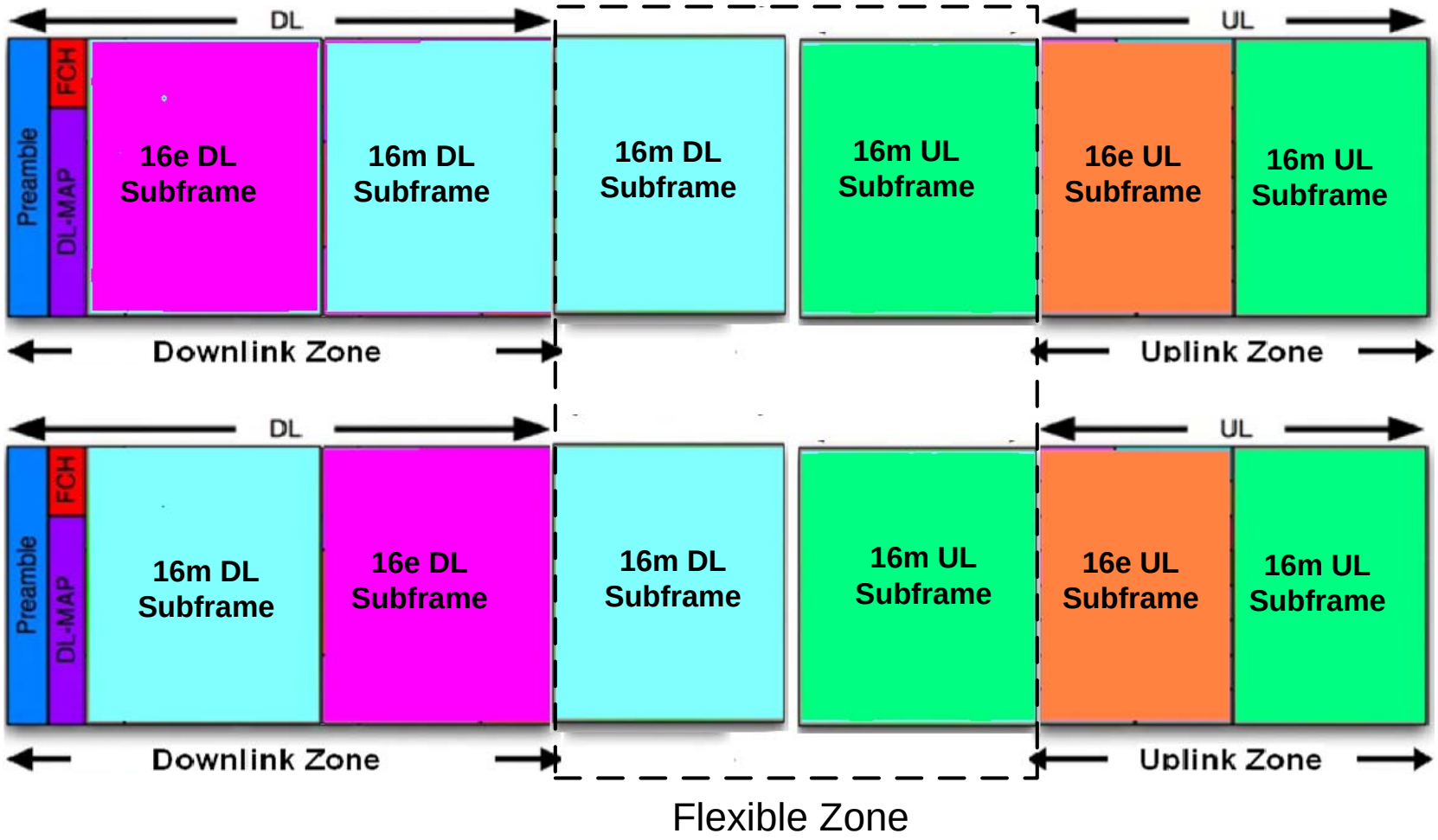
- A Three-Zone Frame Structure:
  - Downlink Zone: It is for downlink transmission.
  - Flexible Zone: It is for both downlink/uplink transmission
  - Uplink Zone: It is for uplink transmission.
- Length of zone: adjustable (RTG is movable/adjustable)
  - With adjusting the length of flexible zone, the network can control the maximum amount of possible DL/UL interference and inter-system interference.
- With configuring the number and position of DL/UL switching points inside the flexible zone, many frame structure patterns can be generated.
- Since the proposed structure can provide support for one retransmission in two frames, the ACK latency is less than 10ms and satisfies the 16m SRD.

# Flexible Zone Partition (1/4): DUDU Mode

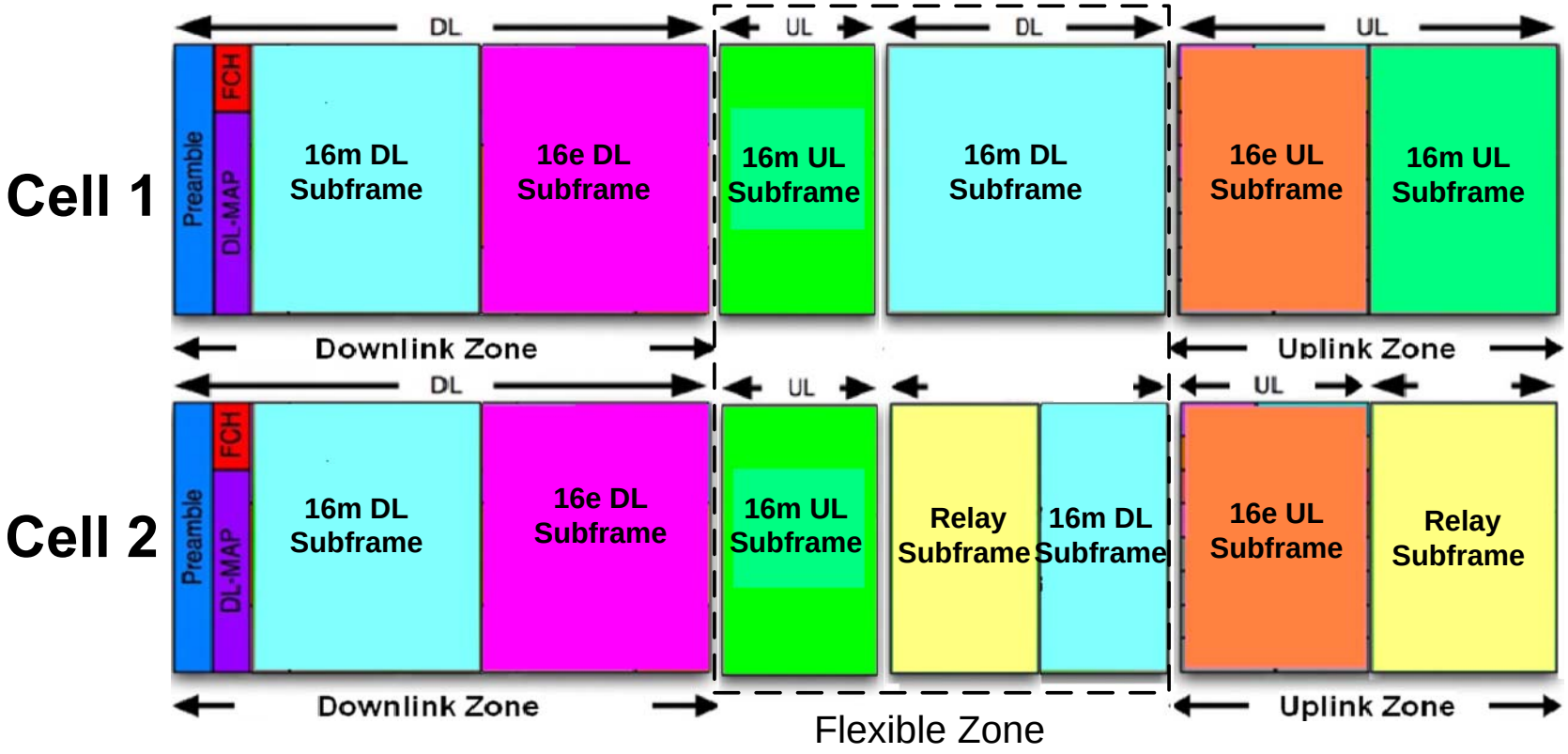



Same as that in IEEE C80216m-07_263

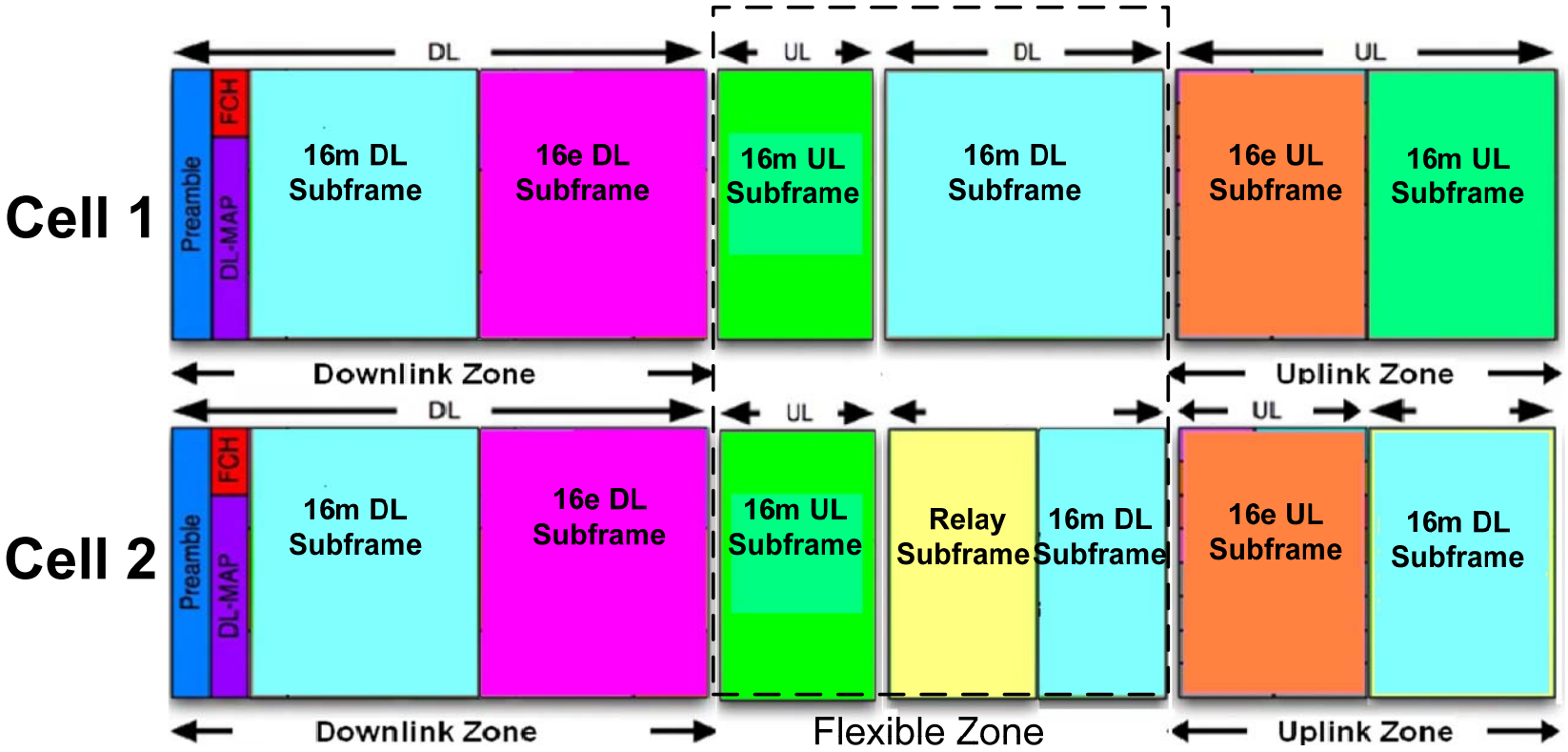
# Flexible Zone Partition (2/4): DDUU Mode



# Flexible Zone Partition (3/4): Relay Example 1

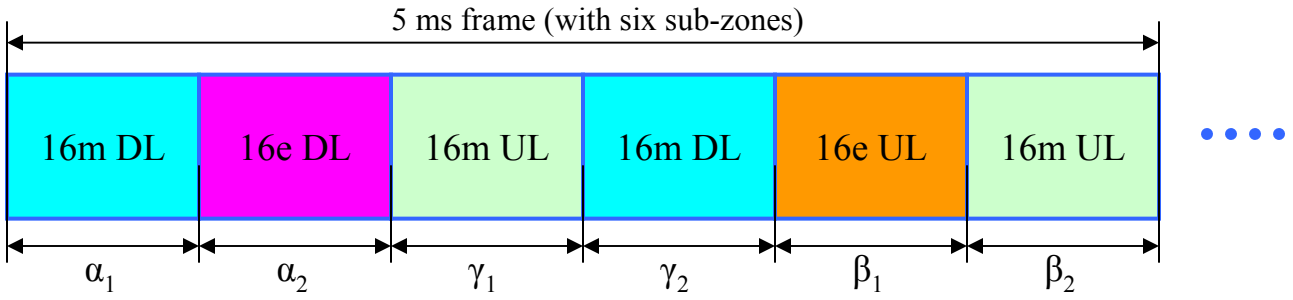


# Flexible Zone Partition (4/4): Relay Example 2



# Latency Analysis Example

- Frame structure under Analysis




- Case 1.1: BS sends a packet at the 1st DL zone
  - Subcase 1.1.1: at the beginning of the 1st DL zone (7.5ms)
  - Subcase 1.1.2: at the rear of the 1st DL zone (9.17ms)
- Case 1.2: BS sends a packet at the 2nd DL zone
  - Subcase 1.2.1: at the beginning of the 2nd DL zone (10ms)
  - Subcase 1.2.2: at the rear of the 2nd DL zone (9.17ms)
- Worst-Case Latency Calculation
  - Values specified: $\alpha_1=\alpha_2=\beta_1=\beta_2=\gamma_1=\gamma_2= 5/6$ ms
  - Results: (above values in blue)

# Harmonization Opportunity

- This frame structure can be flexibly configured to accommodate the requirements from various upper layer services.
- This frame structure can also be configurable to be compatiable with the frame structure proposals from many member companies.

# Conclusion

- Several views regarding frame structure design are suggested.
- A 3-zone flexible frame structure is proposed. It can be configured to be
  - DDUU-type frame structure, or
  - DUDU-type frame structure.
- The proposed frame structure framework can also support the transmission of rely subframes.