Uplink Numerology for E-UTRA

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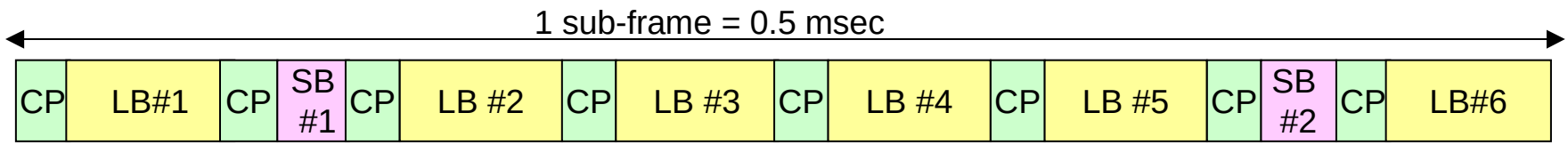
Candidates for UL Sub-Frame Structure

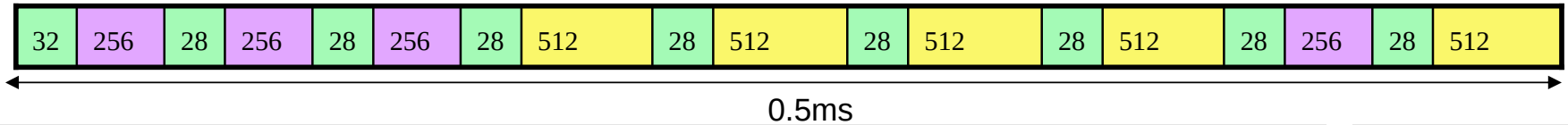
- In TR 25.814 and TR 25.912, UL sub-frame structure is defined as



- At Cannes meeting, an alternative UL sub-frame structure was discussed that 1st LB can be split into two SBs [1] [2]
  - DL associated ACK/NAK, CQI are assigned in the first new SB
  - The neighboring new SB is served as the corresponding reference signals
  - Potentially maintain low PAPR for UEs which needs transmit UL data and DL oriented controls within a sub-frame
- This contribution raises concerns on the numerology of the new sub-frame structure

New UL Sub-Frame Structure

- **New sub-frame needs an additional CP**
- **Assumptions**
  - The new two SBs are also generated by DFT-S-OFDM
  - The total samples in 0.5ms are fixed
- **Concerns**
  - The CP of the 1st LB with 31 samples are shared by the new two SBs. It would be 16 samples(≈ 2.08μs,) at most. Compared to the other CP with 31 samples (≈ 4.04μs), the length of new CPs are relatively short and far from the maximum time spread 5μs in TU channel model
- **Solution**
  - "Borrow" additional samples from the other 7 CPs
  - Example for 5MBW: 5 LBs + 4 SBs in a sub-frame
    - the numeral in a region denotes the number of samples



Numerology for New UL Sub-Frame Structure

Parameter Setting	Bandwidth (MHz)					
	1.25	2.5	5	10	15	20
FFT size	128/64	256/128	512/256	1024/512	1536/768	2048/1024
Useful symbol duration (μs)	66.7/33.3	66.7/33.3	66.7/33.3	66.7/33.3	66.7/33.3	66.7/33.3
Total symbol duration (μs)	69.79/36.46	70.31/36.98	70.31/36.98	70.31/36.98	70.31/36.98	70.31/36.98
CP & Ramp overhead	7.14%	7.14%	7.14%	7.14%	7.14%	7.14%
CP samples	6	14	28	56	84	112
CP duration (μs)	3.125	3.6458	3.6458	3.6458	3.6458	3.6458
CP duration (μs/samples)×8,(μs/samples)×1	(3.13/6)×8, (8.33/16)×1	(3.65/14)×8, (4.17/16)×1	(3.65/28)×8, (4.17/32)×1	(3.65/56)×8, (4.17/64)×1	(3.65/84)×8, (4.17/96)×1	(3.65/112)×8, (4.17/128)×1
Ramp up+down samples	10	2	4	8	12	16
Ramp up+down duration (μs)	5.2083	0.5208	0.5208	0.5208	0.5208	0.5208

Numerology - Guard Time

- Total overhead of guard time
  - 7.14% for any bandwidth
- Consideration for ramp up/down time
  - Reserve additional guard time duration for ramp
  - The low bandwidth of 1.25MHz is assigned more guard time for ramp than other bandwidth configuration or further discussion is needed

Numerology - Scalable Bandwidth Impacts

- Numerology setting for different bandwidth should be of consistent consideration
- In a 20MHz system, coexistence between the UEs with 10MHz capability and those with 20MHz capability should be perfectly time aligned, i.e. to keep the FFT window boundary aligned with each other, the difference of CP duration applied by UEs with different capabilities should be no more than one sample to avoid more cumulating offsets in the following samples

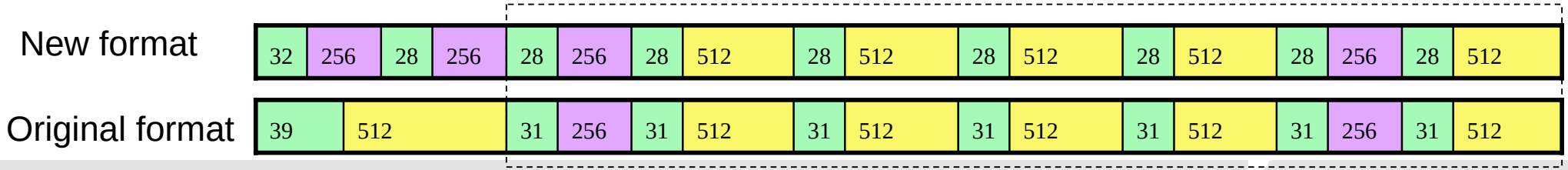
Numerology - CP Duration

- **CP duration may contain time window overlap duration which is considered for out-of-band emission**
  - The window overlap reduces the effective CP duration
  - For all bandwidths from 1.25~20M, the CP duration must offer sufficient window overlap samples to meet the UMTS spectral mask requirement
- **CP duration should meet coverage requirement**
  - Minimum CP duration is 3.125μs, larger than absolute propagation delay with ISD less than 1000m
- **The new UL sub-frame structure enlarges the CP duration difference between UL and DL** (3.65μs/UL, 4.69μs/DL)
- **The main purpose of CP is avoiding ISI introduced by multi-path channel**
  - Related with time delay spread character of the multi-path channel
  - Shorter CP duration may impact demodulation performance, but longer CP duration increases overhead

Numerology - CP vs. ISI

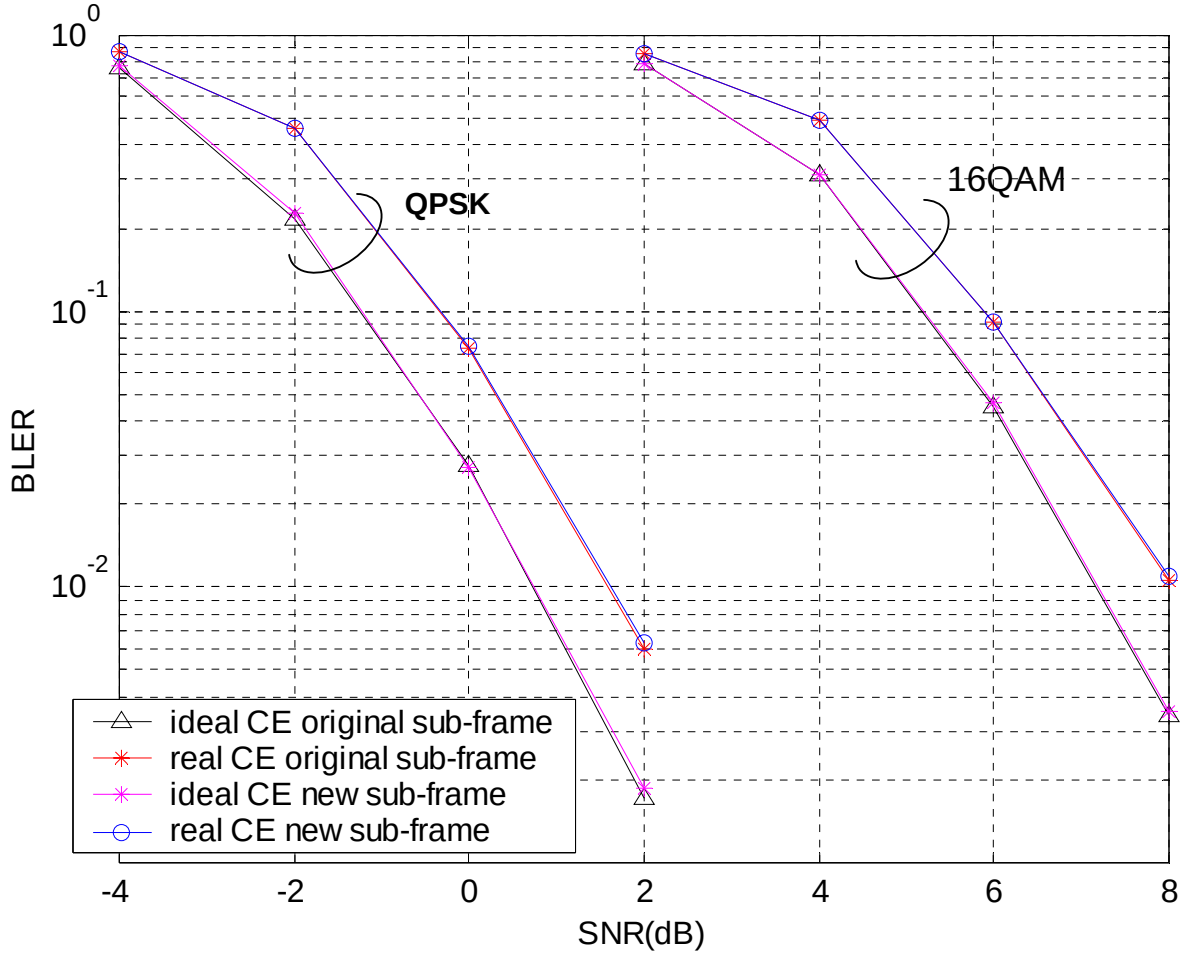
- Simulation assumptions
  - All the LBs in a sub-frame are used to transmit modulated symbols belonging to the same coded block
  - Pad random symbols into the 1st LB in the original format and the new two SBs in the new format

Parameter		Setting
Bandwidth		5 MHz (2.0GHz)
Pulse shaping		No
Time window overlapping		No
Channel Model		6-ray TU, Velocity=30kmh
Turbo Coding		Rate ½
Data Modulation		QPSK, 16QAM
Number of Sub-Carriers		300 for LB,150 for SB
Data Channel		localized FDMA (RPF=1)
Reference Signal Channel		Localized FDMA (RPF=1)
Antenna		1 Tx, 2 Rx
Channel Estimation	Time Interpolation	Linear Average
	Frequency Interpolation	Least Squares
Reference Signal to Data Channel Power Ratio		0dB



Numerology - CP vs. ISI

- The new sub-frame with shorter CP duration impacts little on BLER



Summary

- A new UL sub-frame of splitting 1st LB into 2 SBs needs an additional CP
- The needed samples for the additional CP can be borrowed from the other CPs'
- The resulting 9 CPs of the new UL sub-frame have shorter duration than before, e.g. 28 samples (3.65μs) than 31 samples (4.04μs) for 5MBW without increasing overhead
- Shorter CP duration (≈ 3.65μs) introduces little performance degradation in 6 Ray-TU multi-path channel

Reference

[1] R1-061794, Qualcomm Europe,“Numerology for E-UTRA”

[2] R1-061862, Ericsson, “Uplink Non-data-associated Control Signaling”