TDD Frame Structure – 2 Vs. 4 Switching Point Analysis

Document Number:

IEEE C802.16m-08/1479

Date Submitted:

2008-11-10

Source:

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RE: IEEE 802.16m-08-042 – "Call for Contributions on Project 802.16m Draft Amendment Content"

Target topic: "Frame Structure"

Purpose:

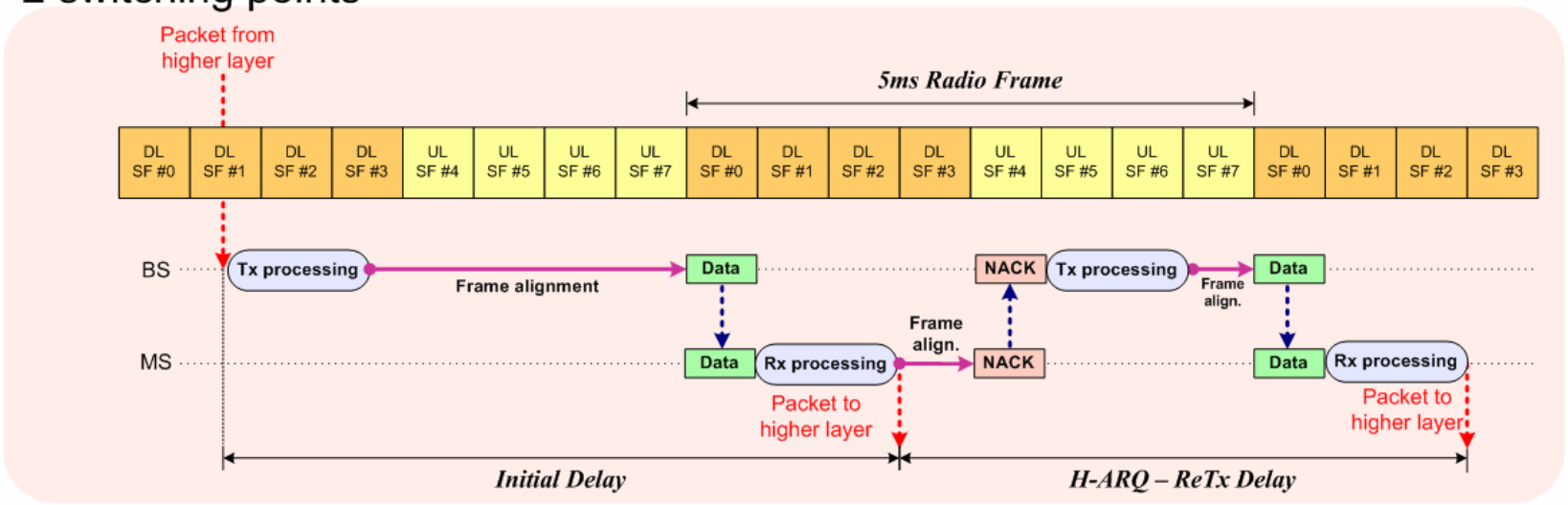
For discussion only

Introduction

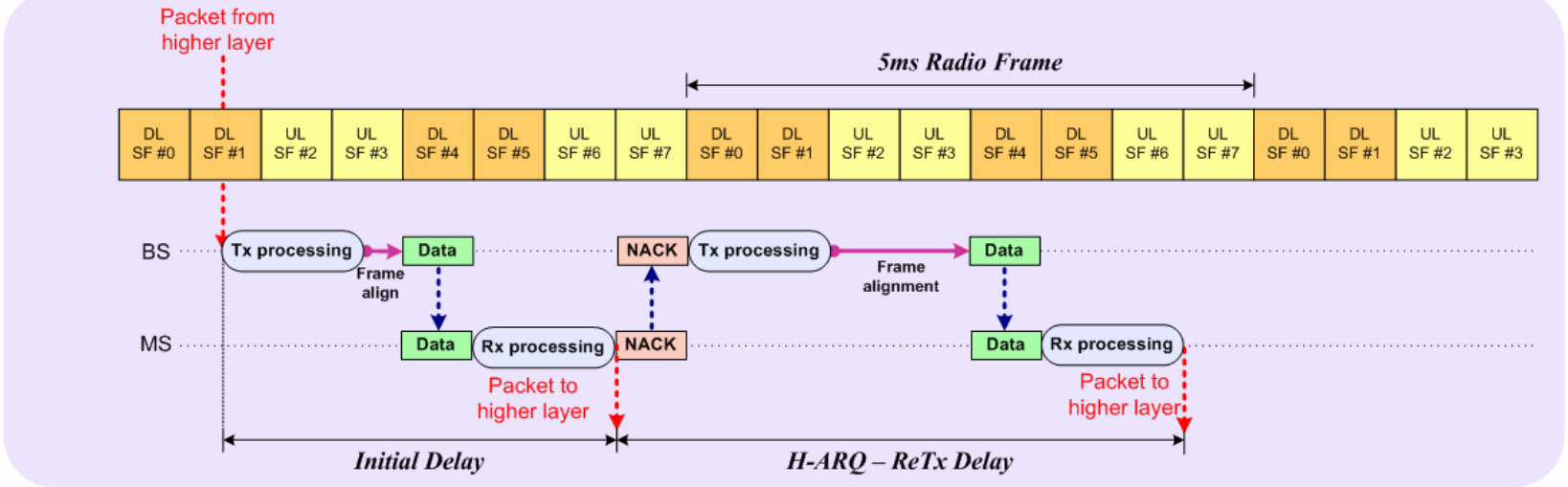
- In session 56 there were open discussions related to the benefits of having 4 switching points as an option within the frame structure.
- In particular contribution C802.16m-08/669 was discussed which included some basic latency analysis along with an evaluation of throughput obtained from system level simulations.
- The authors proposal at the time was to remove 4 switching points as they claimed the performance gain, when compared to the 2 switching point case, was negligible.
- Taking C802.16m-08/669 as a starting point, we have investigated varying BS/MS processing times and the impact this can have on data latency for both the 2 and 4 switching point cases
- This contribution therefore demonstrates the latency reduction gains of having 4 switching points when considering different BS/MS processing times

Downlink Latency - 2vs4 Switching Points

2 switching points



4 switching points

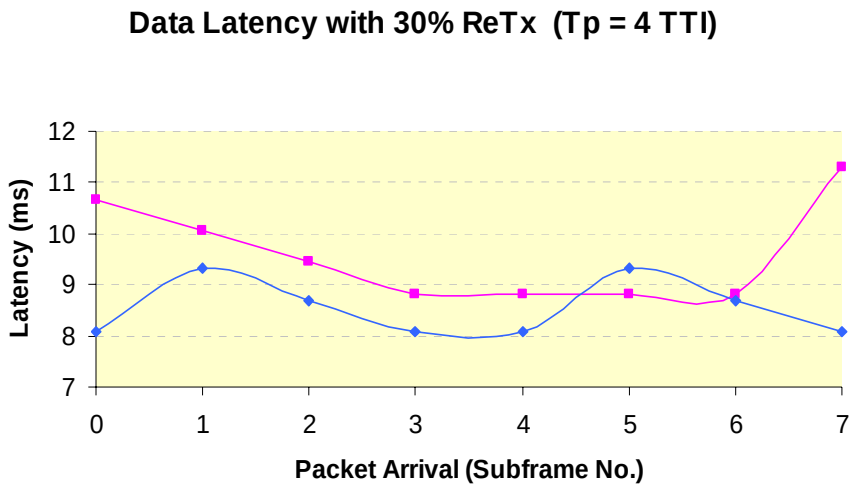


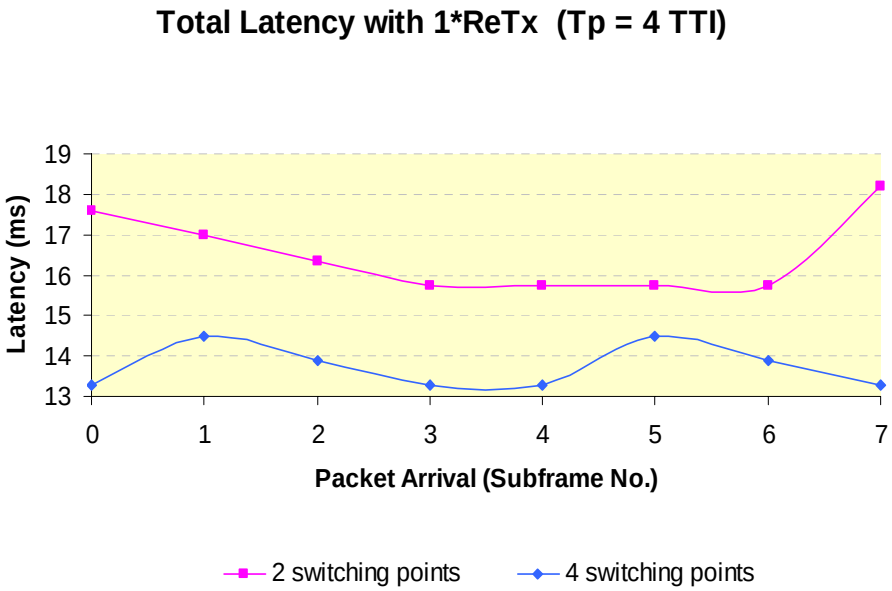
Note, for illustration purposes T_p = 2 subframes where T_p is BS/MS processing time

DL Data Latency with T_p = 4 subframes (worst case)

Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	17.6	13.27	10.68	8.08
1	17.0	14.50	10.06	9.32
2	16.4	13.89	9.44	8.70
3	15.7	13.27	8.83	8.08
4	15.7	13.27	8.83	8.08
5	15.7	14.50	8.83	9.32
6	15.7	13.89	8.83	8.70
7	18.2	13.27	11.29	8.08
Average	16.51	13.73	9.60	8.55

	4 SP Gain (%)
Delay with 30 % ReTx (ms)	10.93
Total Latency with 1 ReTx (ms)	16.82

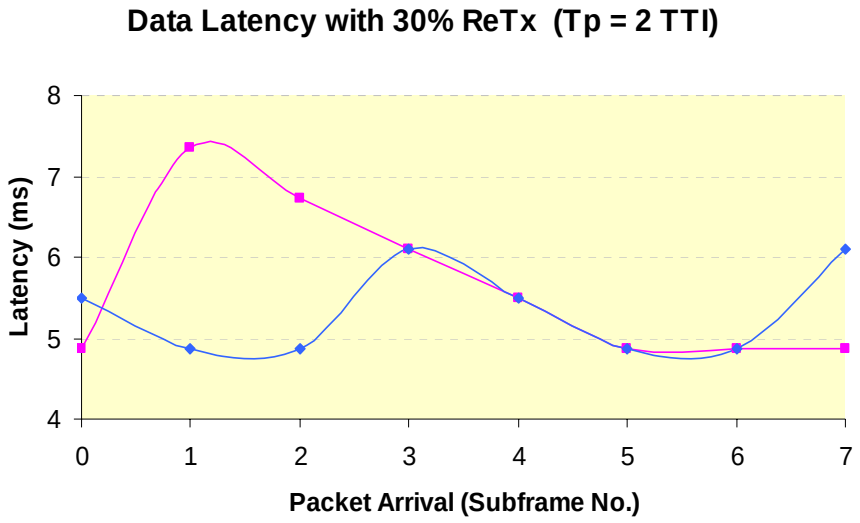


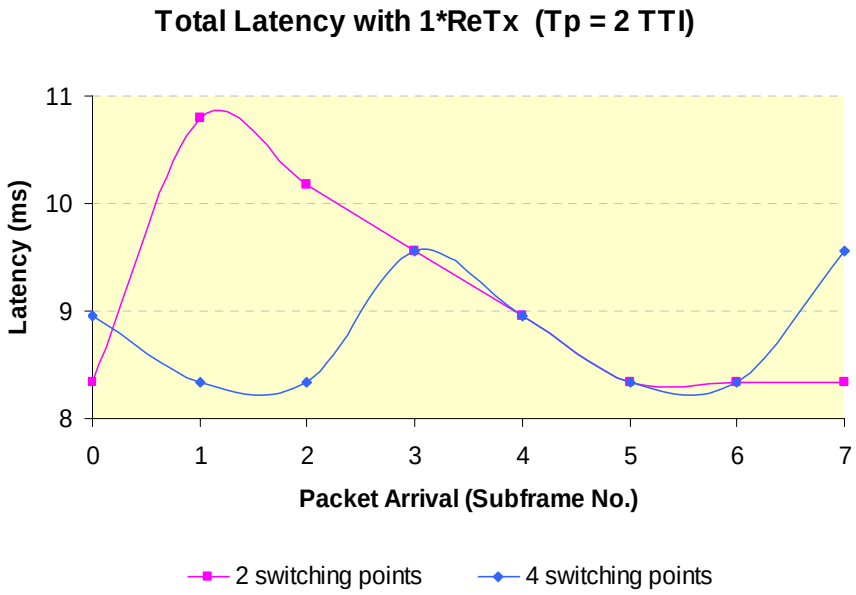


DL Latency with T_p = 2 subframes

Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	8.33	8.95	4.88	5.49
1	10.80	8.33	7.34	4.88
2	10.18	8.33	6.73	4.88
3	9.57	9.57	6.11	6.11
4	8.95	8.95	5.49	5.49
5	8.33	8.33	4.88	4.88
6	8.33	8.33	4.88	4.88
7	8.33	9.57	4.88	6.11
Average	9.10	8.79	5.65	5.34

	4 SP Gain (%)
Delay with 30 % ReTx (ms)	5.46
Total Latency with 1 ReTx (ms)	3.39

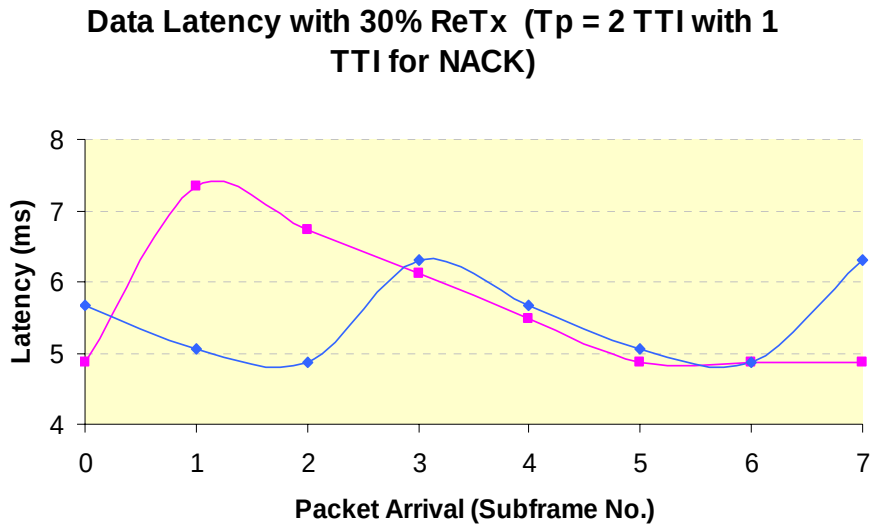


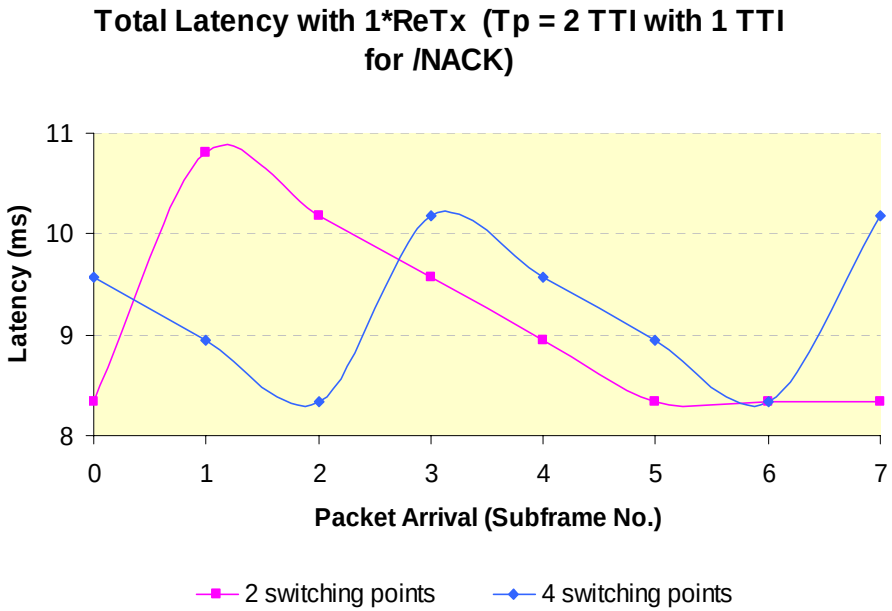


DL Latency with T_p = 2 subframes (1 subframe for NACK)

Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	8.3	9.57	4.88	5.68
1	10.8	8.95	7.34	5.06
2	10.2	8.33	6.73	4.88
3	9.6	10.18	6.11	6.30
4	8.9	9.57	5.49	5.68
5	8.3	8.95	4.88	5.06
6	8.3	8.33	4.88	4.88
7	8.3	10.18	4.88	6.30
Average	9.10	9.26	5.65	5.48

	4 SP Gain (%)
Delay with 30 % ReTx (ms)	3.01
Total Latency with 1 ReTx (ms)	-1.69 (loss)

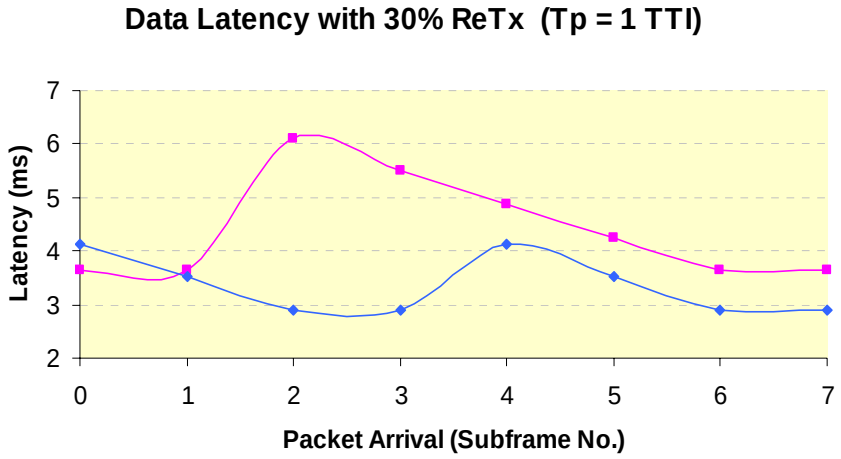


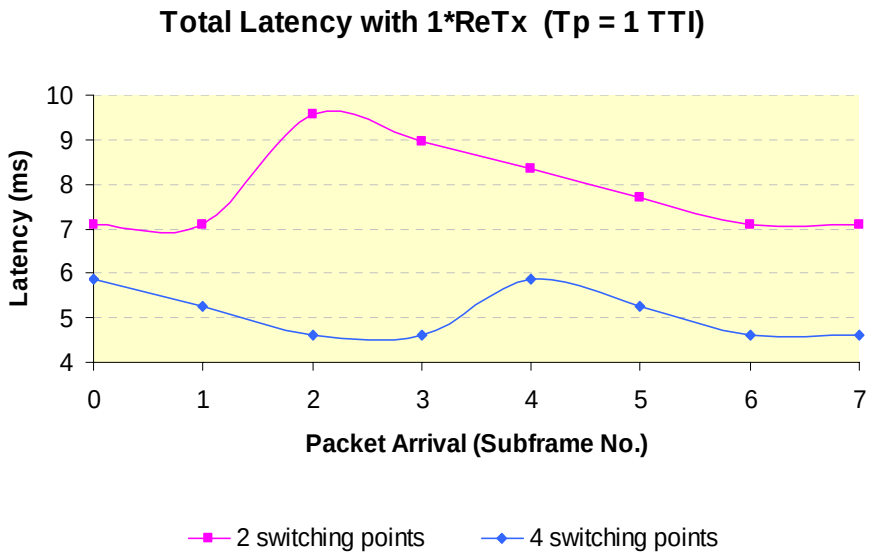


DL Latency with T_p = 1 subframe

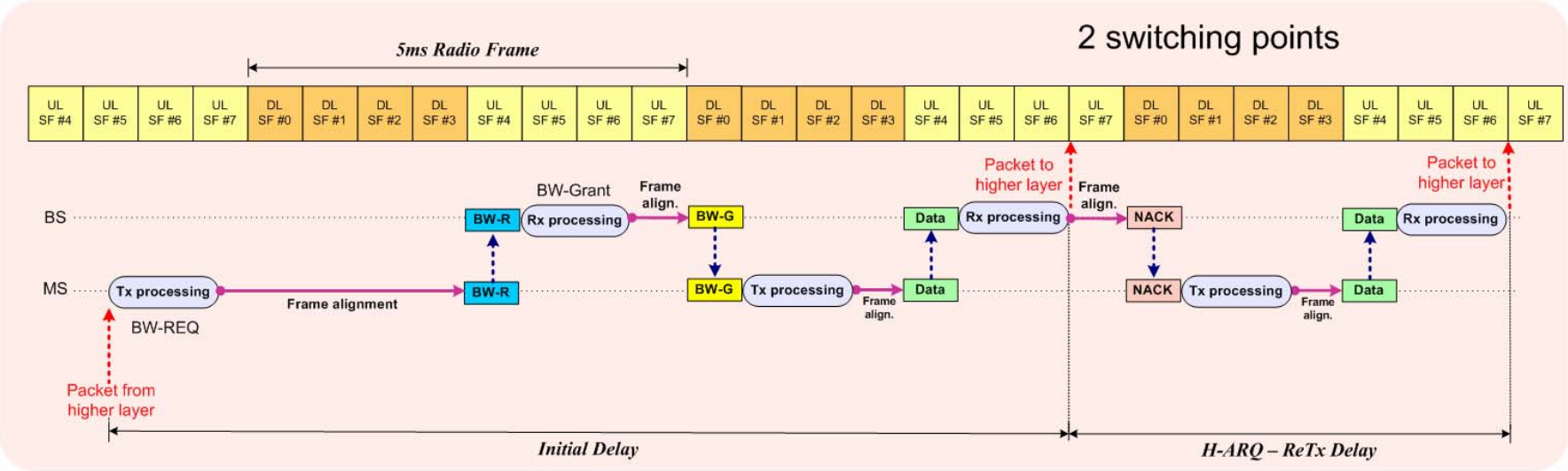
Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	7.1	5.86	3.64	4.13
1	7.1	5.25	3.64	3.52
2	9.6	4.63	6.11	2.90
3	8.9	4.63	5.49	2.90
4	8.3	5.86	4.88	4.13
5	7.7	5.25	4.26	3.52
6	7.1	4.63	3.64	2.90
7	7.1	4.63	3.64	2.90
Average	7.87	5.09	4.41	3.36

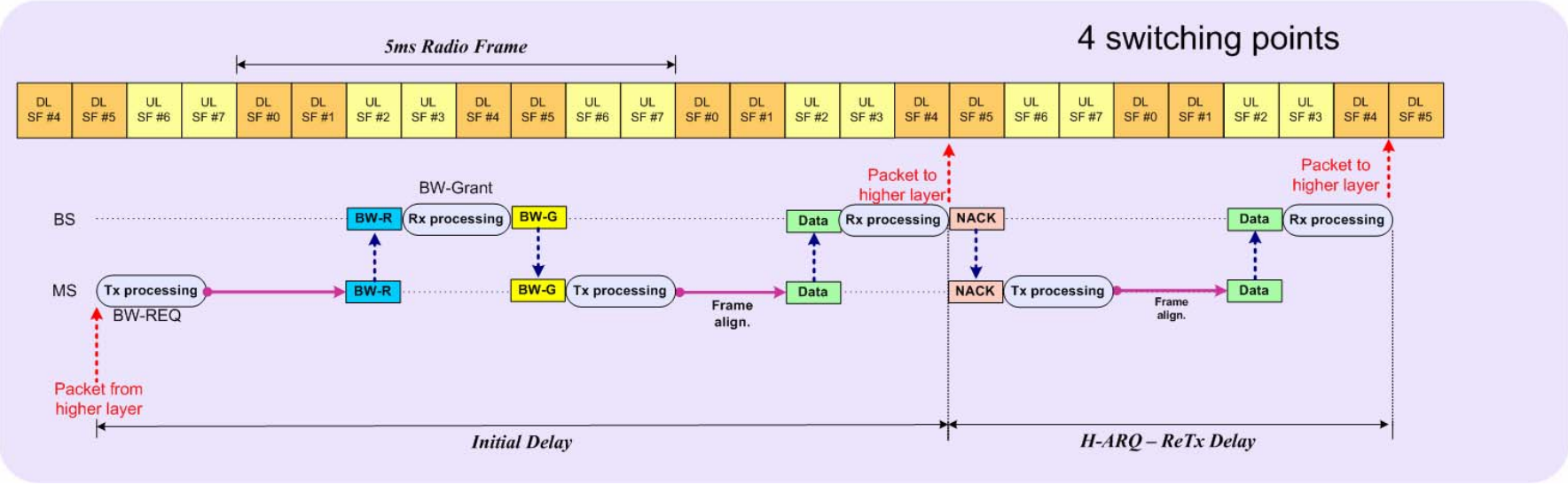
	4 SP Gain (%)
Delay with 30 % ReTx (ms)	23.78
Total Latency with 1 ReTx (ms)	35.29





Uplink Latency - 2vs4 Switching Points



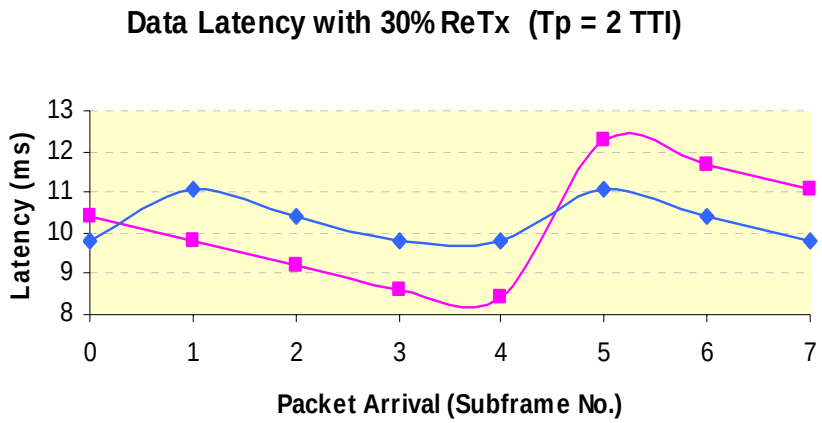


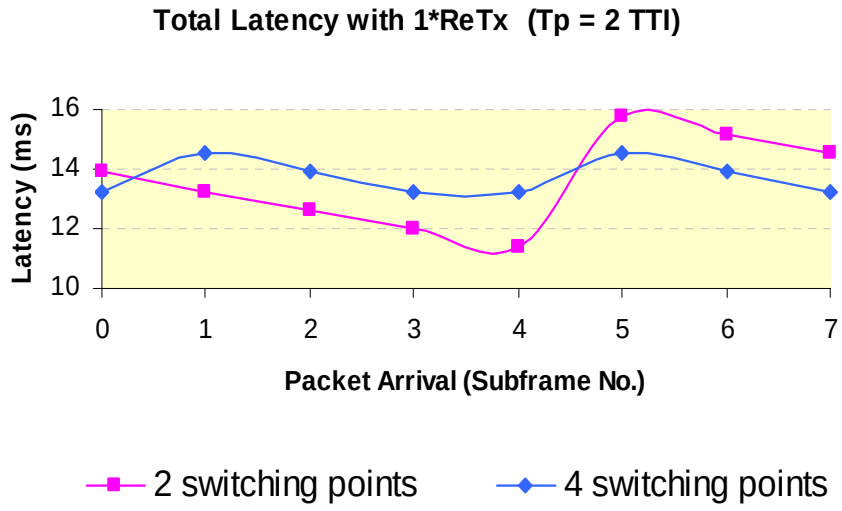
Note, for illustration purposes T_p = 2 subframes where T_p is BS/MS processing time

UL Latency with T_p = 2 subframes

Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	13.89	13.27	10.43	9.81
1	13.27	14.50	9.81	11.05
2	12.65	13.89	9.20	10.43
3	12.03	13.27	8.58	9.81
4	11.42	13.27	8.39	9.81
5	15.74	14.50	12.28	11.05
6	15.12	13.89	11.66	10.43
7	14.50	13.27	11.05	9.81
Average	13.58	13.73	10.18	10.28

	4 SP Gain (%)
Delay with 30 % ReTx (ms)	-0.986 (loss)
Total Latency with 1 ReTx (ms)	-1.136 (loss)

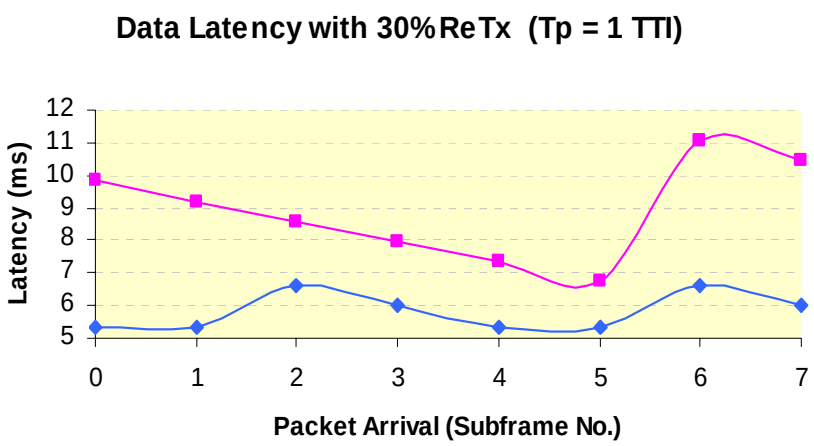


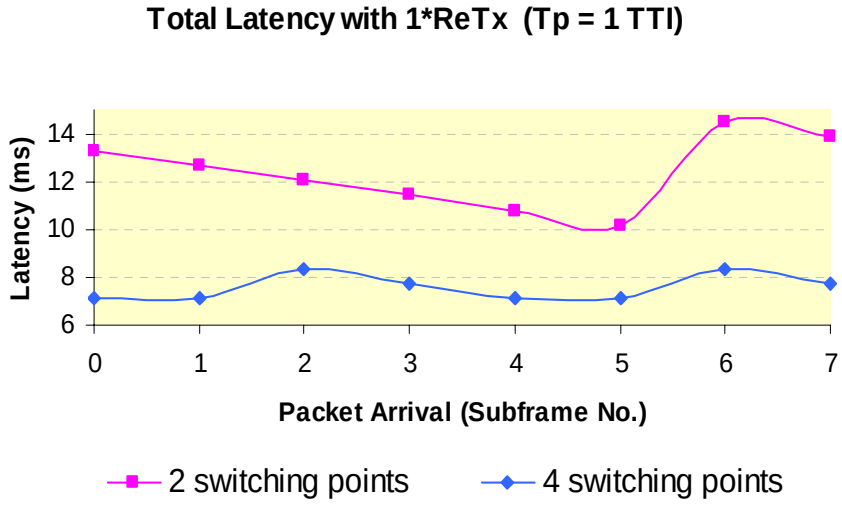


UL Latency with T_p = 1 subframe

Packet arrival (Subframe)	Total Latency with 1 ReTx (ms)		Delay with 30 % ReTx (ms)	
	2 SP	4 SP	2 SP	4 SP
0	13.27	7.10	9.81	5.37
1	12.65	7.10	9.20	5.37
2	12.03	8.33	8.58	6.60
3	11.42	7.71	7.96	5.99
4	10.80	7.10	7.34	5.37
5	10.18	7.10	6.73	5.37
6	14.50	8.33	11.05	6.60
7	13.89	7.71	10.43	5.99
Average	12.34	7.56	8.89	5.83

	4 SP Gain (%)
Delay with 30 % ReTx (ms)	34.38
Total Latency with 1 ReTx (ms)	38.75



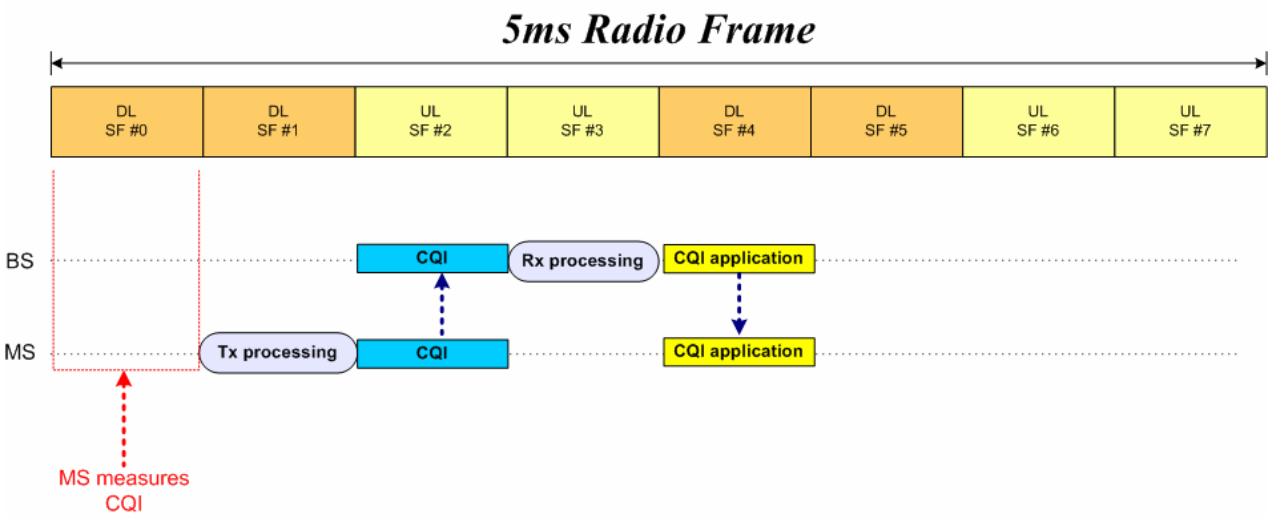


Latency - Summary and Conclusion

	Downlink Gain (%)		Uplink Gain (%)	
Processing time Tp (subframes)	Total Latency with 1 ReTx	Delay with 30% ReTx	Total Latency with 1 ReTx	Delay with 30% ReTx
1	35.29	23.78	38.75	34.38
2	3.39	5.46	-1.136	-0.986
2 with 1 for NACK	-1.69	3.01	-	-
4	16.82	10.93	-	-

- With a range of different processing times, it is clear that the having 4 switching points can further improve latency, especially in the case where the BS and MS processing time is 1 subframe.
- We should not limit the IEEE 802.16m standard by current implementations (i.e., processing speed) and be sure that the AAIF is ‘future-proof’

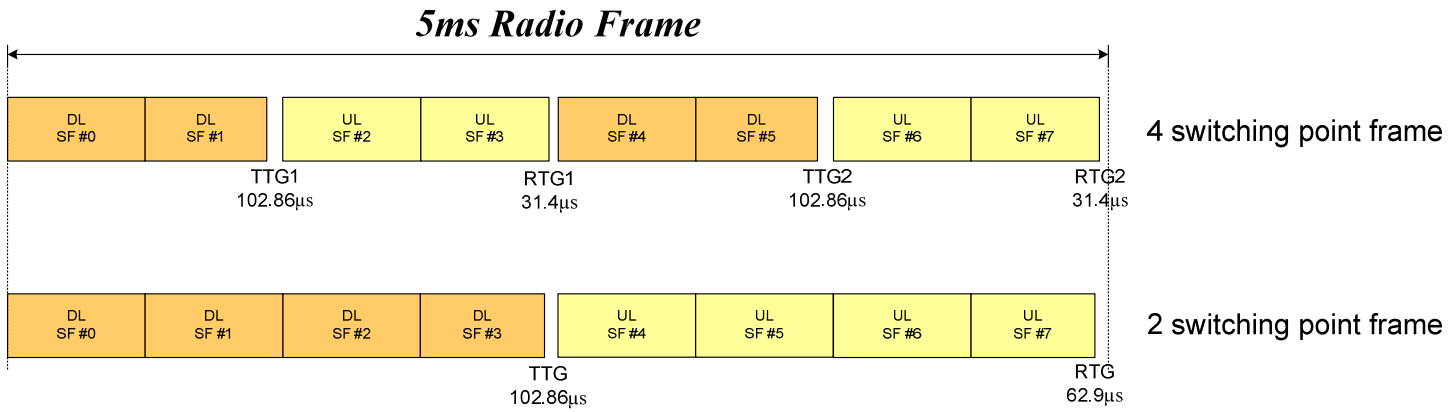
Throughput Analysis

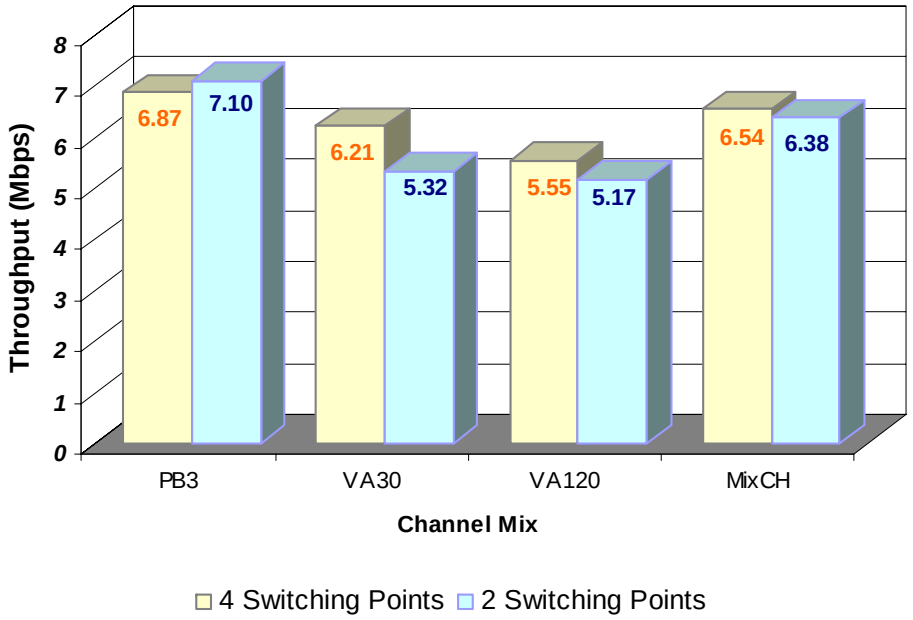


Assumptions:

- Simulation conditions based on 16m EMD (004r3)
- MS and BS processing is 1 subframe
- Pilot CQI measurement
- 2 Switching point DL:UL ratio – 4:4
- 4 Switching point DL:UL ratio – 2:2
- No signalling overhead assumed

Case 1 – Throughput analysis

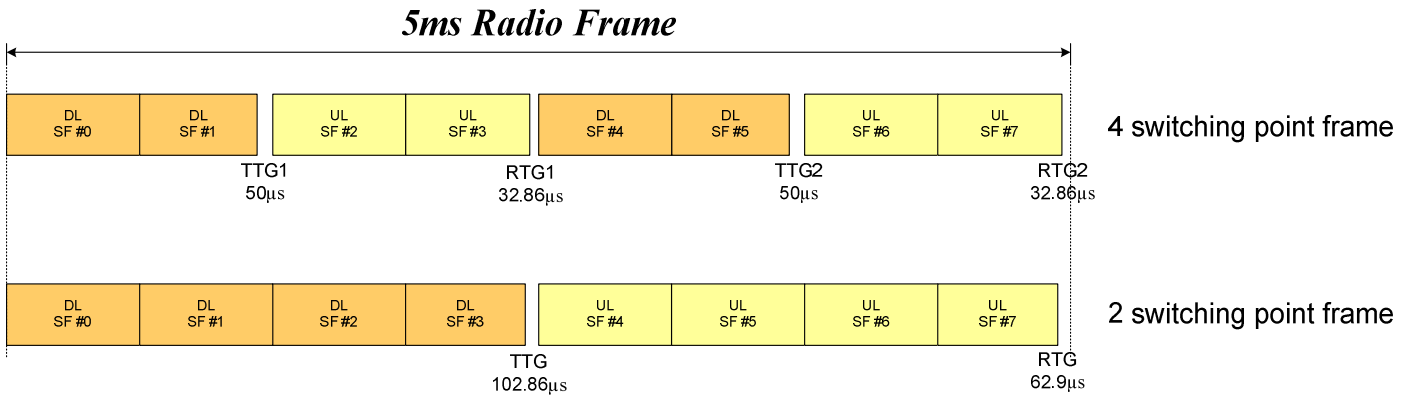


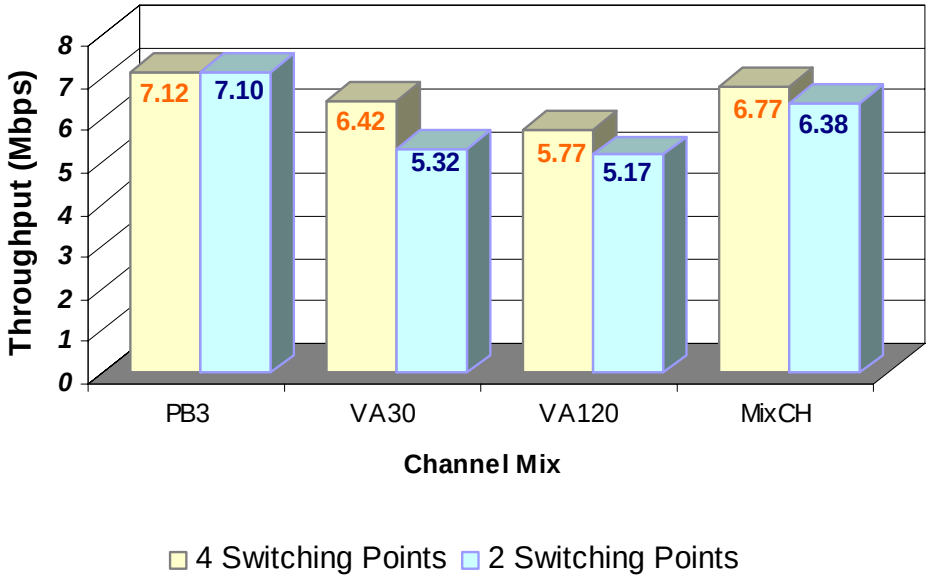


Channel	4 SP Gain (%)
PB3	-3.2
VA30	16.7
VA120	7.4
Mixed	2.5

Note, the 4 switching point frame structure has one less symbol as to accommodate an additional TTG

Case 2 – Throughput analysis





Channel	4 SP Gain (%)
PB3	0.3
VA30	20.7
VA120	11.6
Mixed	6.1

Note, both frames have same number of OFDMA symbols

Conclusion & Recommendation

- Unlike C802.16m-09/669 we have shown that latency is very sensitive to varying BS/MS processing times
- When BS/MS processing time is equal to 1 subframe, the 4 switching point frame can provide 20-40% gain in latency
- Having evaluated the throughput results obtained from system level simulations it is clear having 4 switching points does not degrade system throughput even when an extra symbol is sacrificed for an additional TTG
- It is therefore clear, that the optional 4 switching point frame should remain as to ensure that 802.16m can take advantage of rapid advances in processing technology