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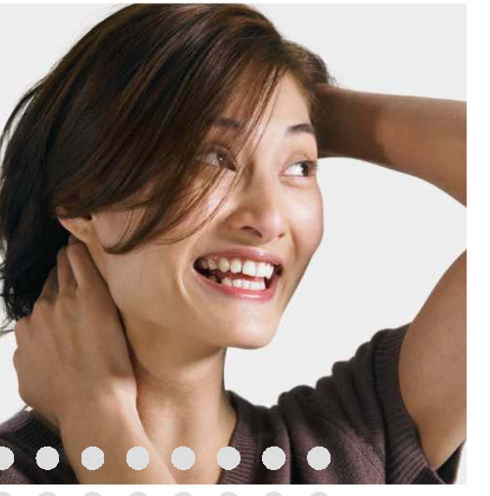
Downlink Coordinated Scheduling

Simulation Results



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Overview

Context:

- 3GPP LTE Rel-8 system augmented by CoMP CS/CB
- Downlink FDD
- Codebook-based closed-loop linear precoding

Objective:

- Reduce interference in the system by coordinated beamforming

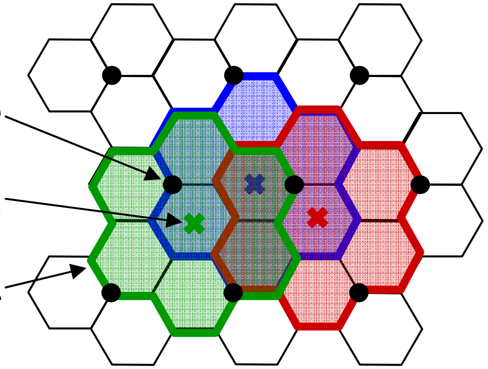
Enablers:

- Multiple PMI (“best/worst companion”) feedback signaling concept
  - Obtain partial CSIT about strongest interfering cells based on codebook
- Cyclically prioritized coordinated scheduling (“CoSch”)
  - Interference avoidance by posing restrictions on the set of available transmit weights

Results:

- sensitivity to multiuser diversity and backhaul latency
- 3GPP Case 1 SCME 3 km/h vs. ITU UMa 3 km/h & 30 km/h

Coordinated scheduling using prioritization to enable distributed computation



Coordination area

- 7 cells
- overlapping

→ simple, but does not cover all strongest interferers due to shadow fading

Cyclic prioritization of scheduling

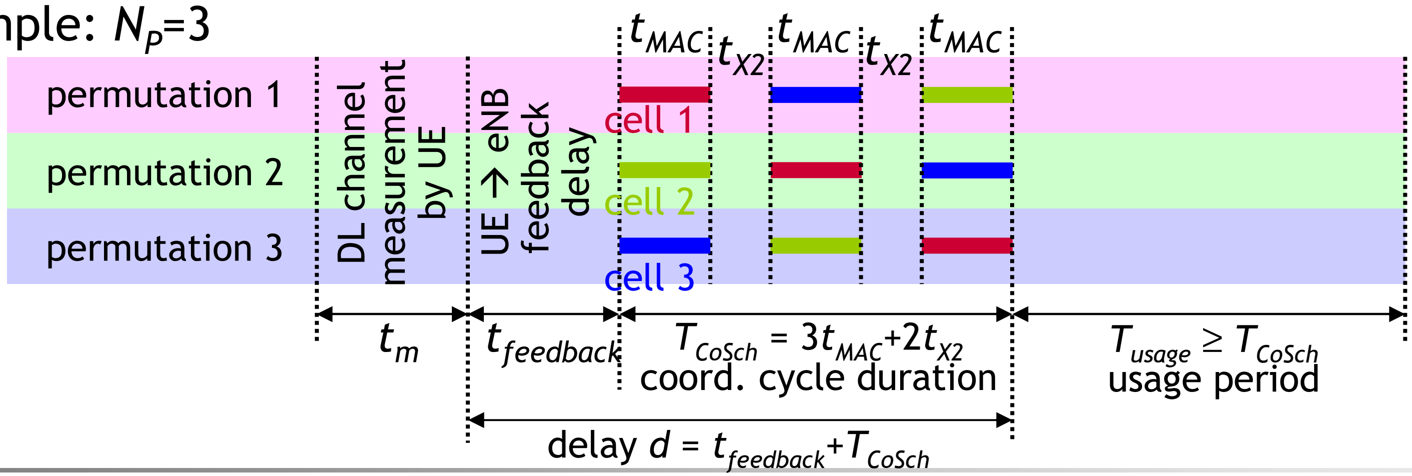
- cell includes results from higher priority cells within its coordination area as constraints to own scheduling
- prioritization prevents conflicting results in the overlap of coordination areas
- fairness among cells achieved by cyclically permuting priority assignments over different frequency bands and/or over time

Frequency selective α-proportional fair scheduling

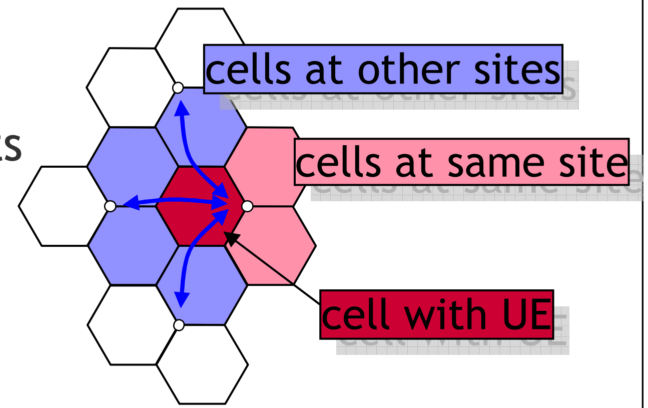
- $score = R_{estimated} / R_{mean}^{\alpha}$, rate estimation based on Delta-CQI reporting
- per subband schedule highest scored UE fulfilling scheduling constraints

Coordinated scheduling – timing

- duration of coordination cycle $T_{CoSch} = N_P t_{MAC} + (N_P - 1) t_{X2}$ depends on
  - number of priorities N_P
  - eNB scheduling computation time (per frequency band) t_{MAC}
  - inter-eNB backhaul communication latency t_{X2}
- measurement to transmission delay $d = t_{feedback} + T_{CoSch}$ increases with T_{CoSch}
- usage period $T_{usage} \geq T_{CoSch}$ (at least) as long as coordination cycle
- permuting priority to eNB assignment to achieve fairness
- Example: N_P=3



The cost:
Increased backhaul requirements & additional reporting in UL



Inter-site communication

- control, no data: scheduling decisions and constraints

X2 bandwidth

- **≤ 3.6 Mbit/s** (@20 MHz) per site, in as well as out
  - 1 used PMI sent to on average * (3+2+0)/3 other sites + 4/(7-1) PMI constraints per cell sent to on average * (4+2+0)/3 cells at other sites = on average 3 PMIs sent out per cell
  - 3 PMIs * 4 bit per PMI * 100 PRB pairs / 1 ms * 3 cells per site = 3.6 Mbit/s

X2 latency

- about **1 ms** one way between sites, higher latency decreases gain

WCI reporting overhead

- **≤ 10.8 kbit/s** (@20 MHz) per UE additional reporting bandwidth in UL
  - (up to) 4 WCIs wideband + 1 Delta-CQI per subband = 4*(4 bit PMI + 3 bit cell ID) + 13*2 bit = 54 bit, reported (at most) every 5 ms

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System Simulation Results

Configuration – 3GPP Case 1 SCME 4x2 SU-MIMO w/ 15 UEs/cell @3 km/h

Parameter	Value
Channel Model	Case 1 SCME 3D
ISD	500 m
velocity	3 km/h
Antenna Algorithm	SenderAlgorithmMultiUserFixedBeams 8 beams
max number of beams	1 beams
Paring Strategy	-
eNB antenna	4 antenna, 0.5λ spacing
UE antenna	2 antenna, 0.5λ spacing
Receiver	MRC
Channel estimation	Ideal
System bandwidth Duplex method	10 MHz FDD
Overhead for control	3 OFDM symbols
Feedback signaling	additional "worst companion" PMI feedback
CSI/CQI granularity	6 PRB
PMI granularity	50 PRB
Feedback interval	5 TTI
Feedback delay	6 TTI
Cooperation set	7 cells (inter-site)
Scheduler	proportional fair
	alpha=0.5/0.6/0.8/1.0/1.3/2.0/3.0
	beta=0.9966
Traffic model	full buffer
HARQ	none
Rank	1
Number of cells	21 (7 sites with 3 cells each), wrap-around
Number of UEs per cell	15
Number of drops	10
TTIs per drop	1000

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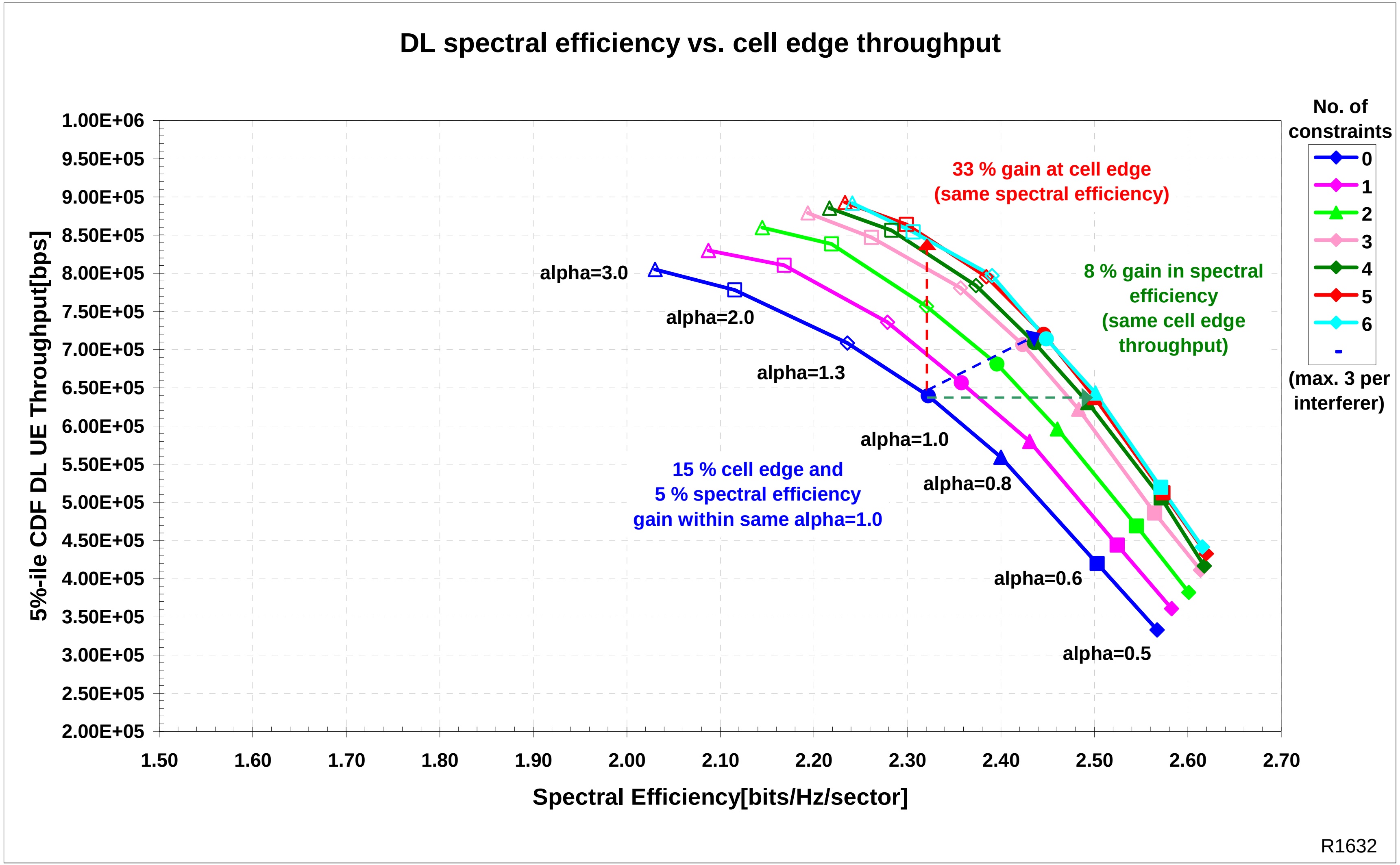
Cell edge vs. spectral efficiency for different alphas



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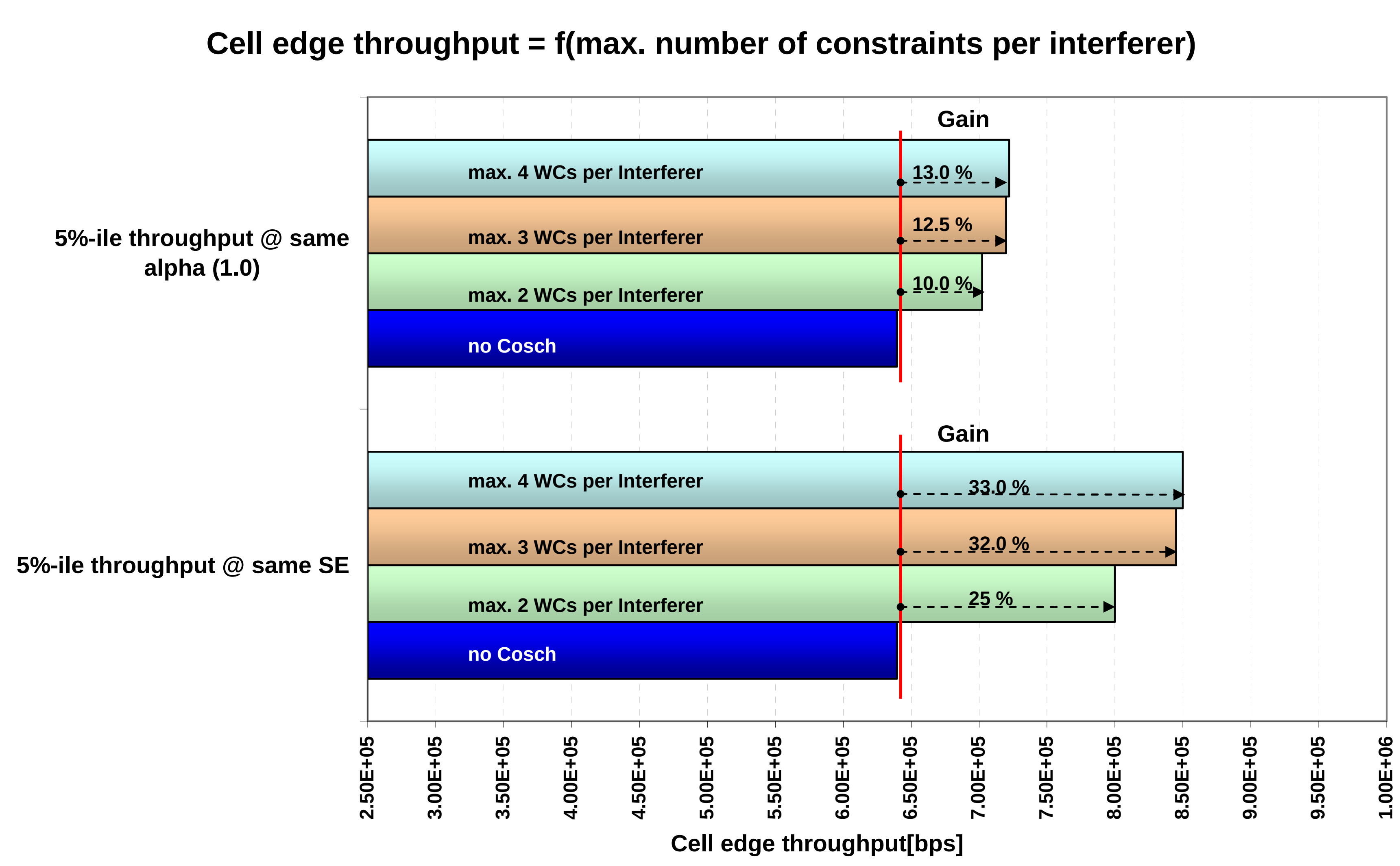
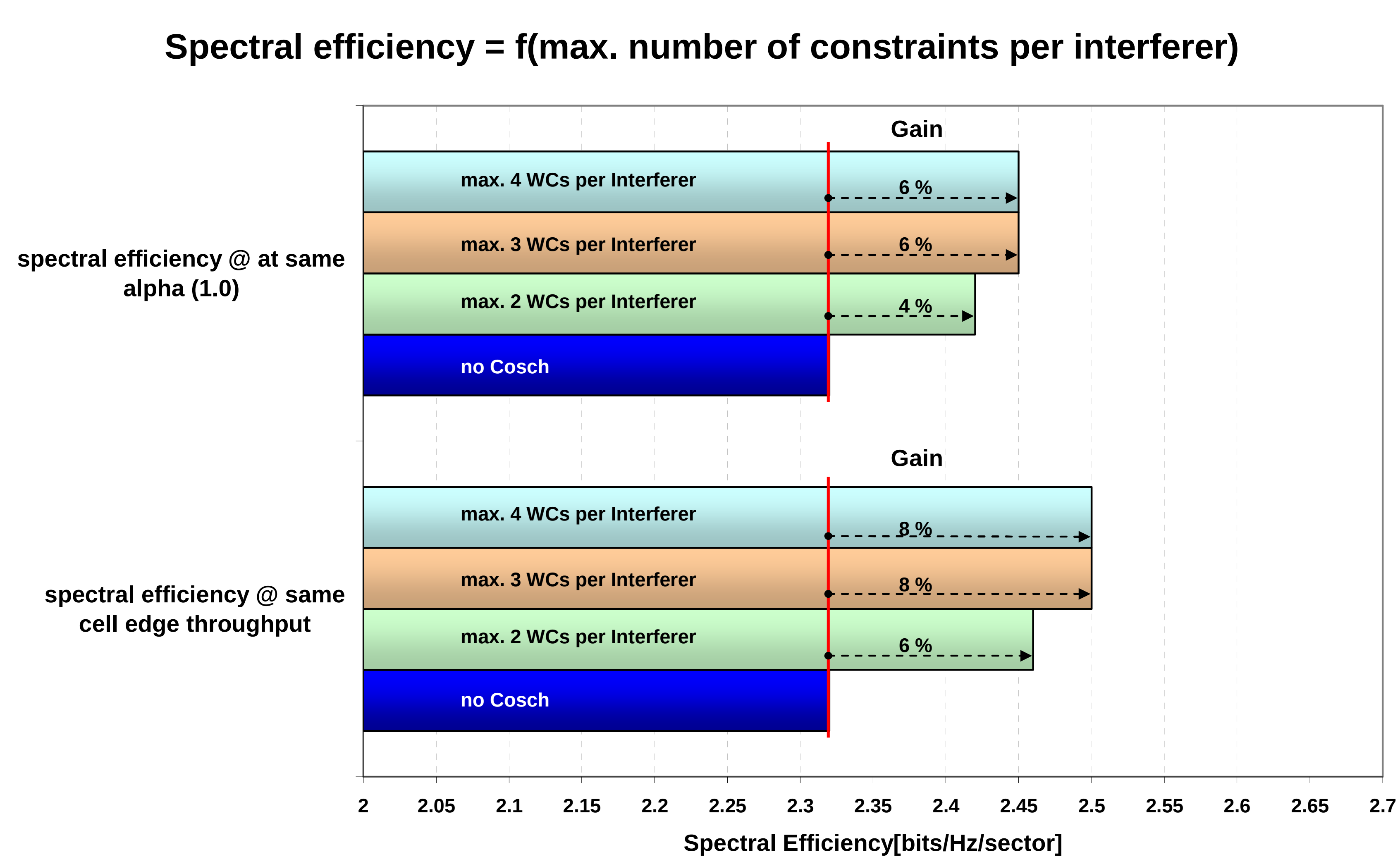
Check: maximum allowed number of constraints per single interferer

max. 2, 3, 4 constraints

Cell edge throughput (Case 1-SCME 4x2 SU-MIMO inter site, 3 km/h)



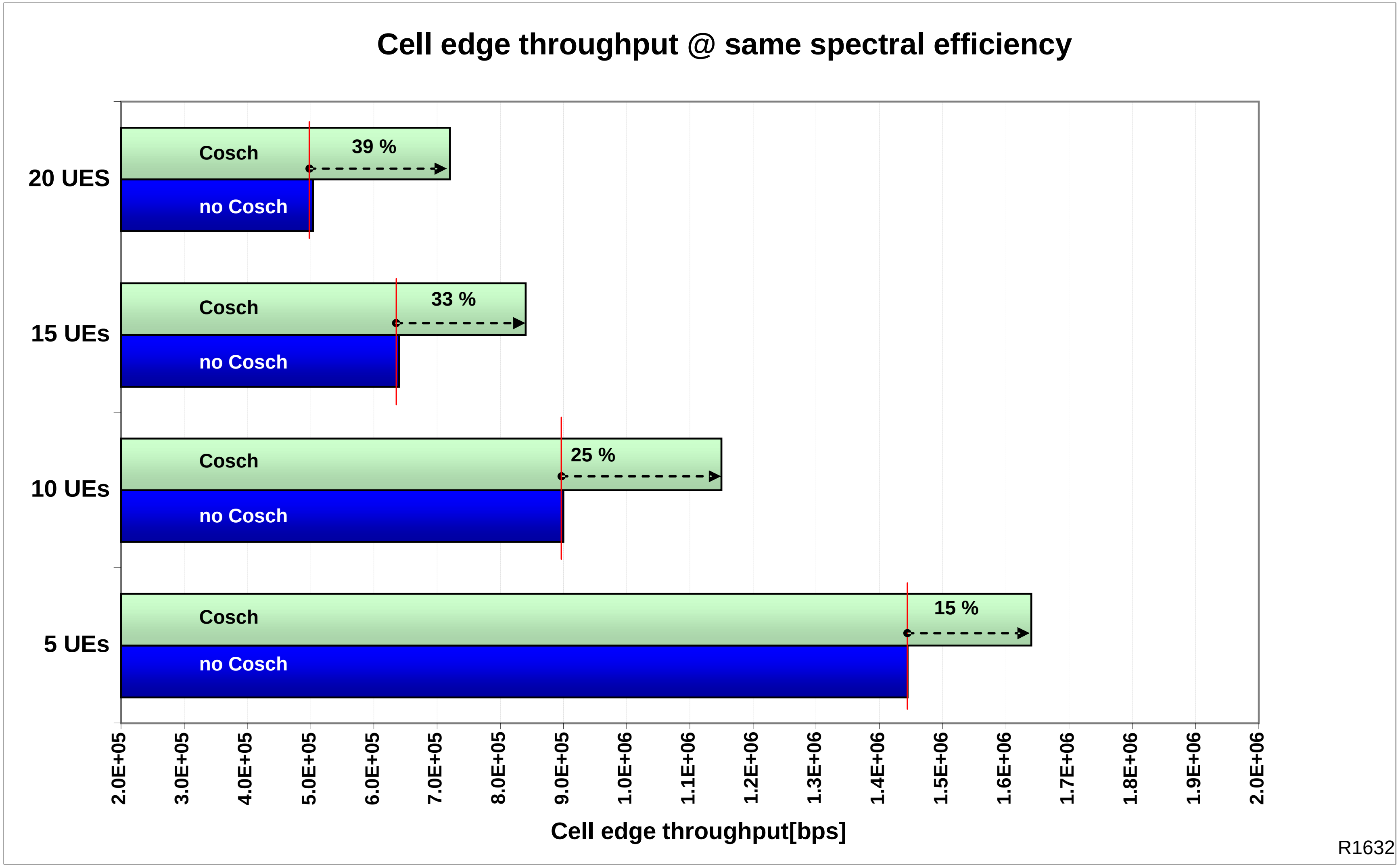
Spectral Efficiency (Case 1-SCME 4x2 SU-MIMO inter site, 3 km/h)



Sensitivity to multiuser diversity

5, 10, 15, 20 UEs per cell on average

Cell edge throughput = f(#UEs) @ same cell spectral efficiency



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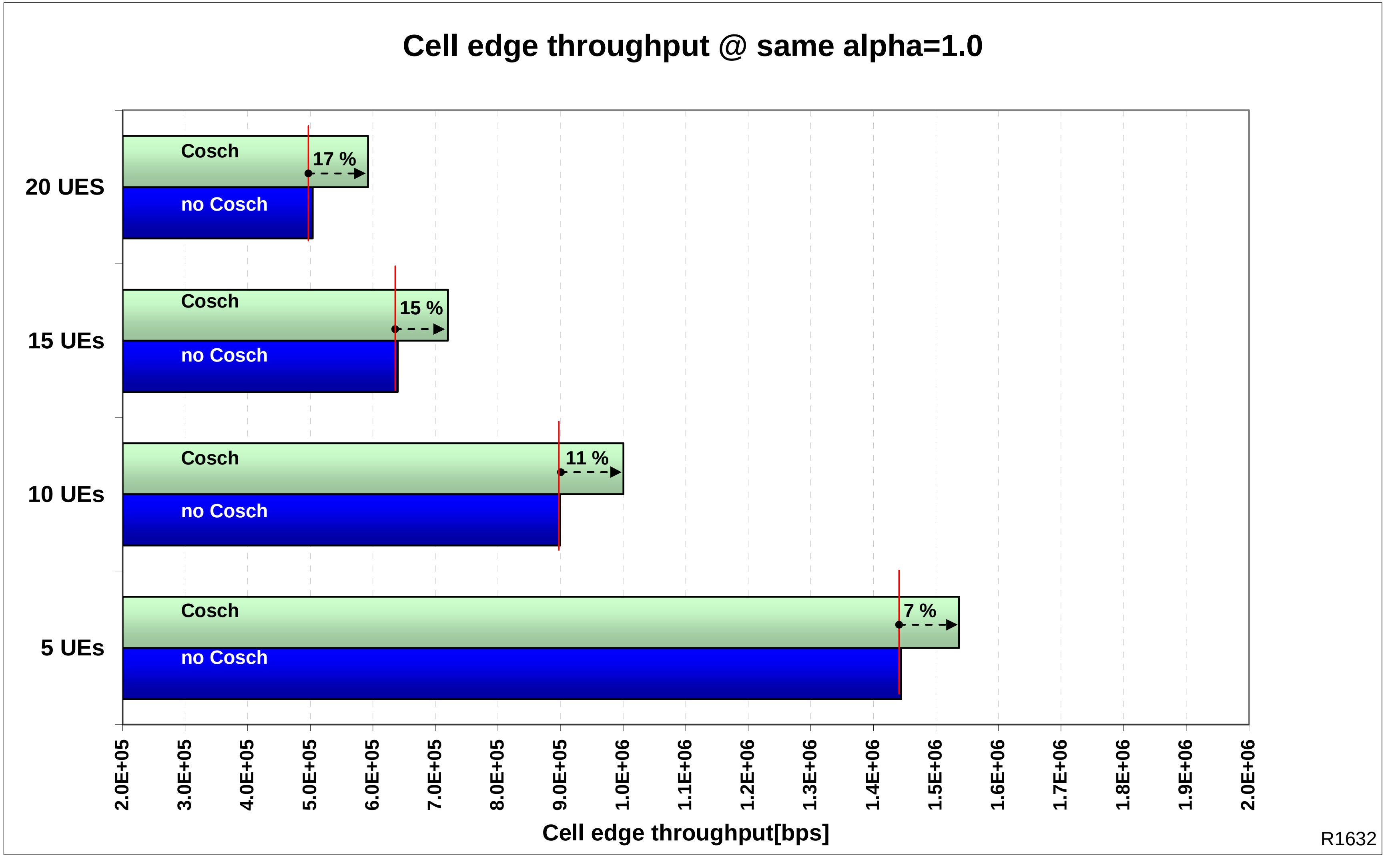
Cell edge throughput = f(#UEs) @ same alpha = 1.0



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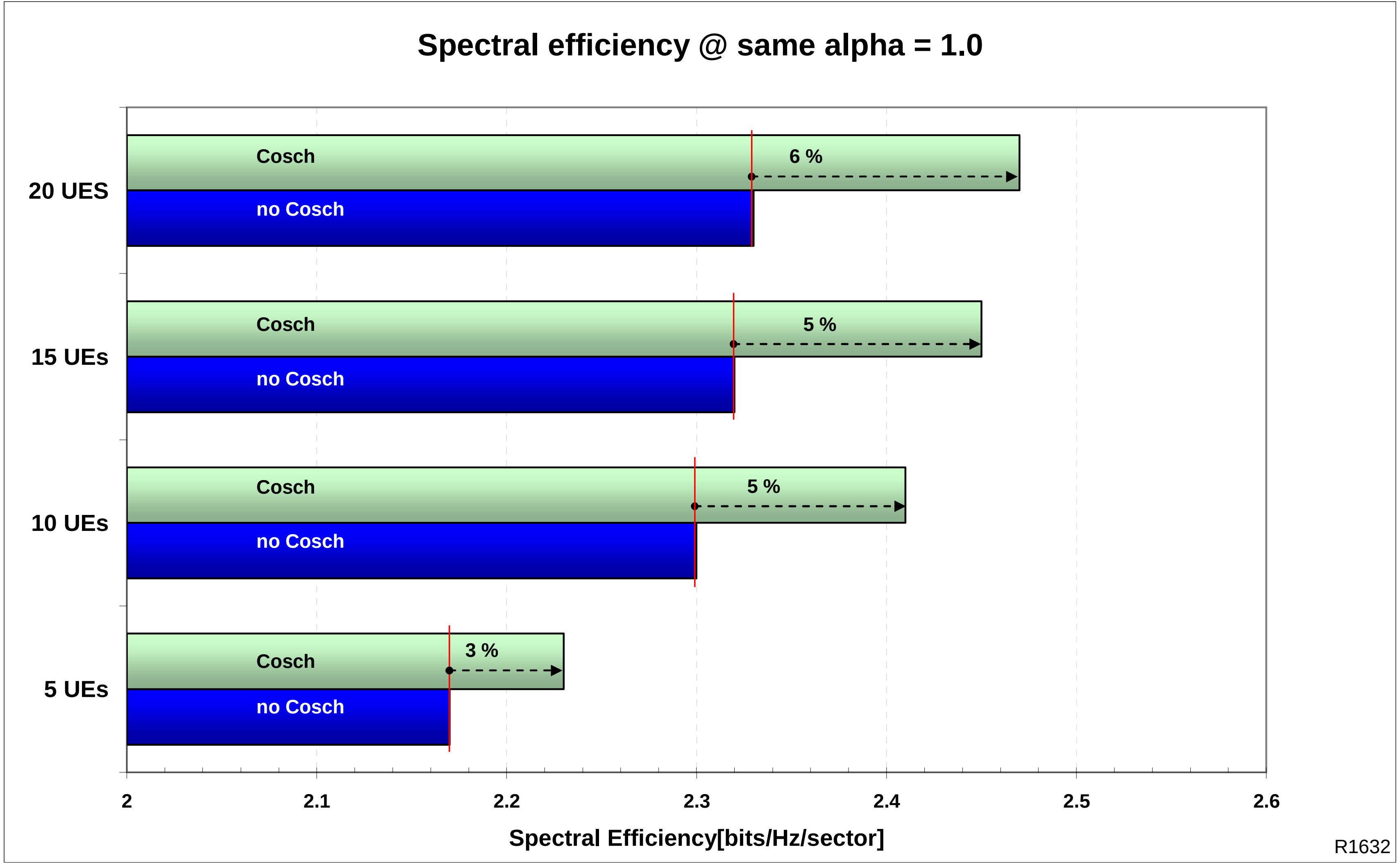

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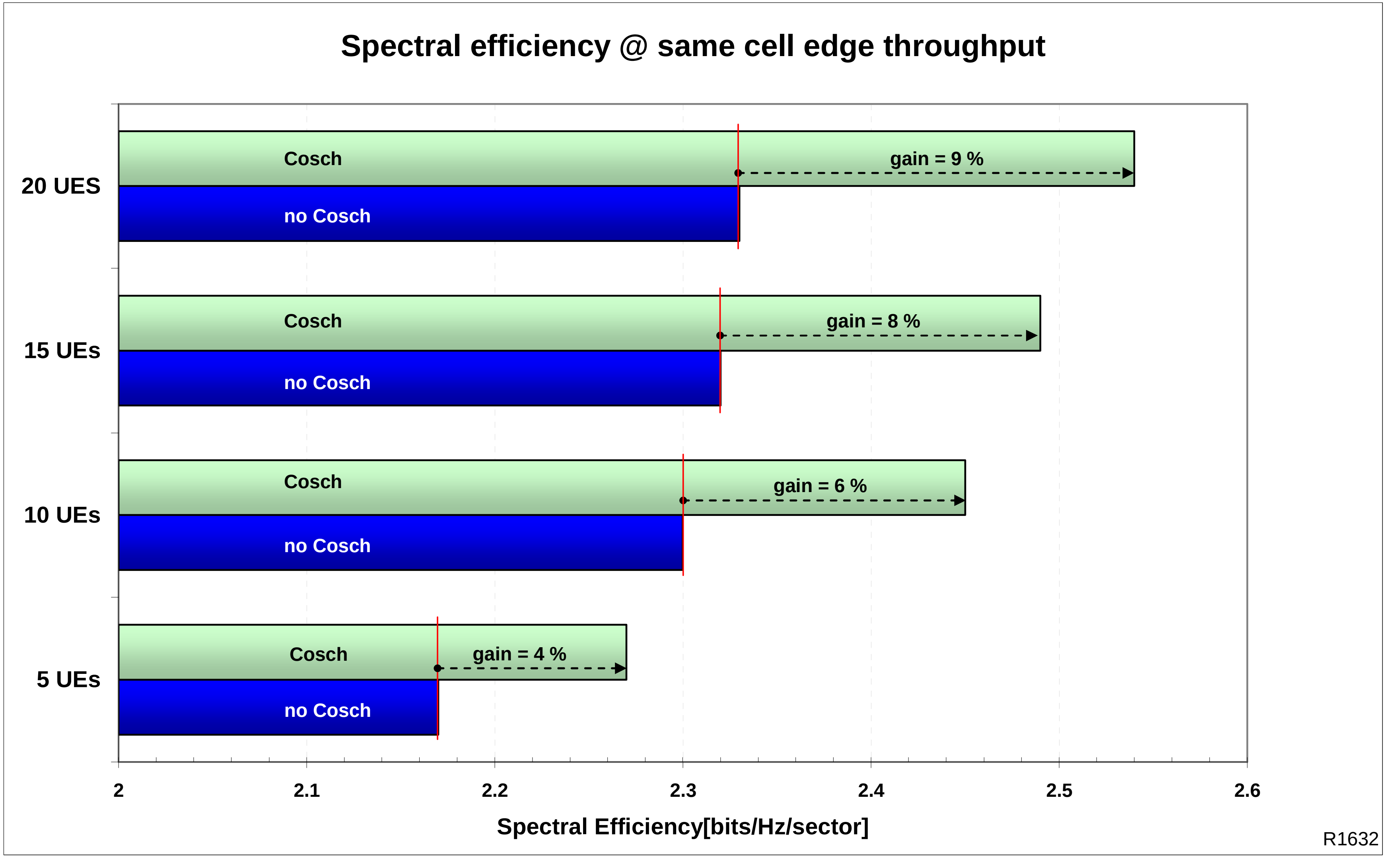
Spectral Efficiency = f(#UEs) @ same cell edge throughput



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Sensitivity to X2 Latency

X2 Latency[§] = 0 ms*, 1 ms, 6 ms

3GPP SCME vs. ITU UMa, 3 km/h vs. 30 km/h

[§] 2*X2 latency + 3*1 ms MAC Processing time + (5+1) ms actual feedback delay = simulated feedback delay

* small enough to fit coordination cycle into 1 ms, i.e. in the order of 100 µs (and assuming a MAC processing time of the same order)

Configuration - (ITU - UMa 4x2 SU-MIMO)

Parameter	Value
Channel Model	**Case 1 SCME 3D, ITU UMa 3D**
ISD	500m
velocity	**3 km/h, 30 km/h**
Antenna Algorithm	SenderAlgorithmMultiUserFixedBeams 8 beams
max number of beams	1 beams
Paring Strategy	-
eNB antenna	4 antenna, 0.5λ spacing
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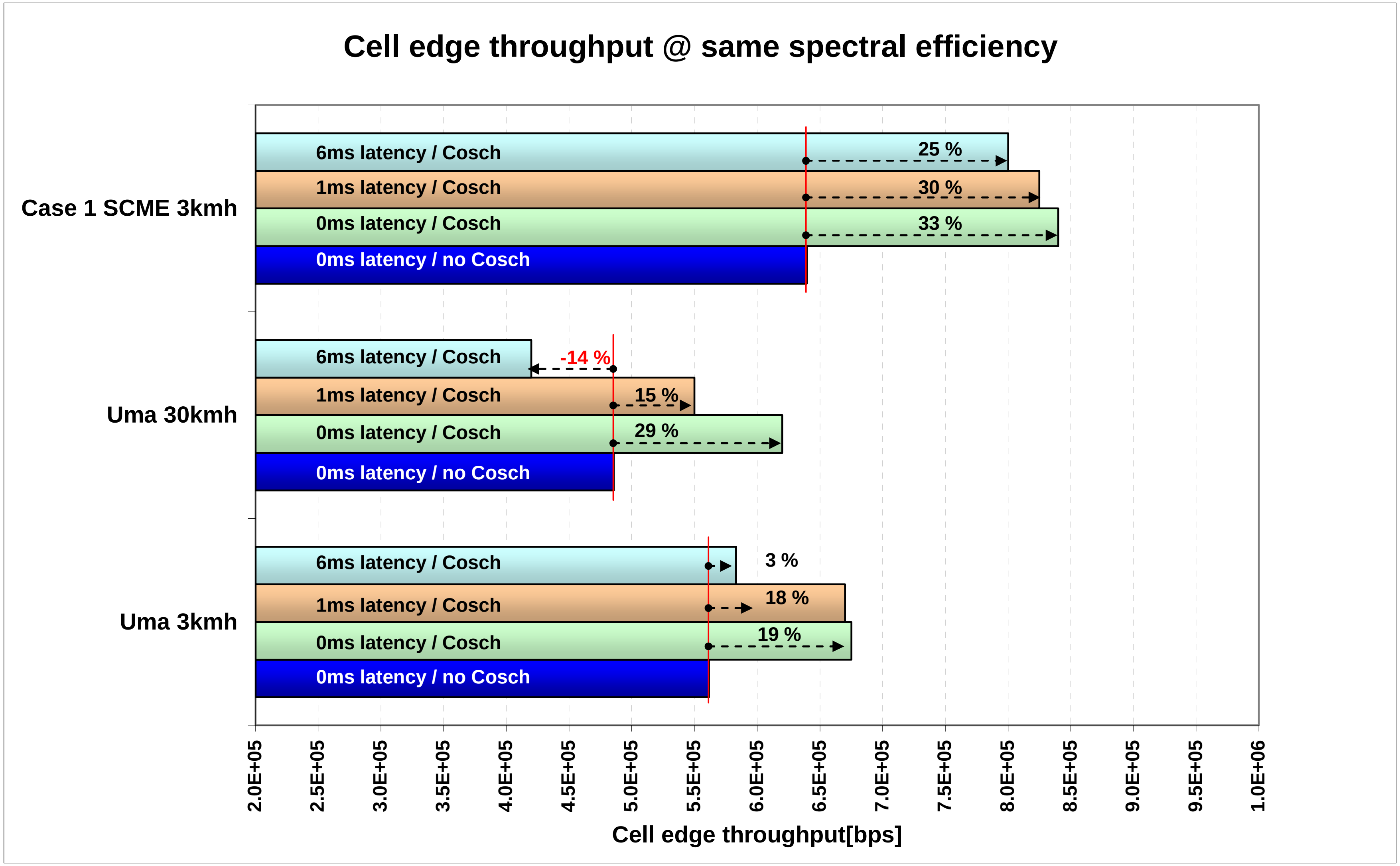
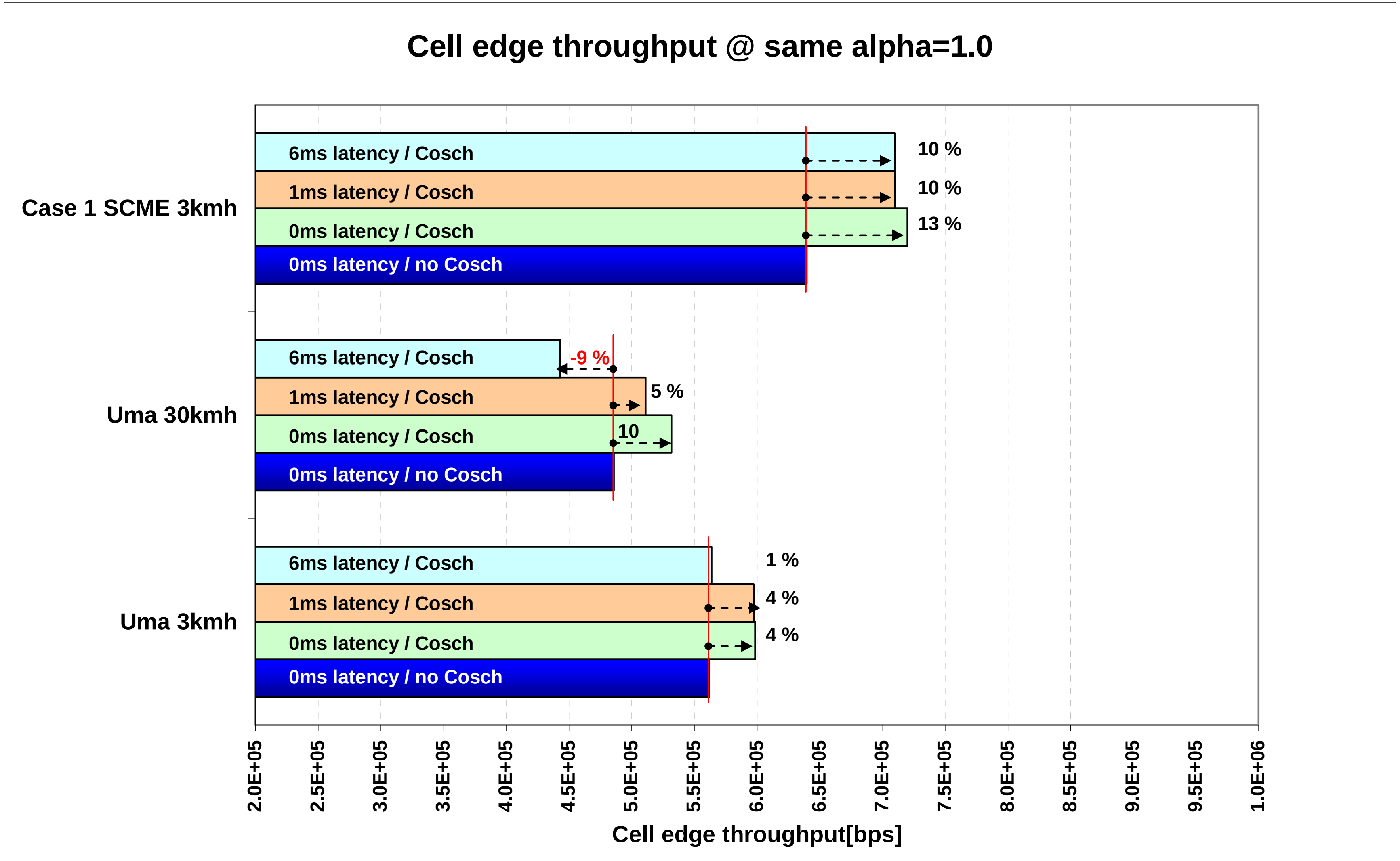
System bandwidth	10 MHz
Duplex method	FDD
Overhead for control	3 OFDM symbols
Feedback signaling	additional "worst companion" PMI feedback
CSI/CQI granularity	6 PRB
PMI granularity	50 PRB
Feedback interval	5 TTI
Feedback delay	**6/11/21 TTI**
Cooperation set	7 cells (inter-site)
Scheduler	proportional fair
	alpha=0.5/1.0/2.0/3.0
	beta=0.9966
Traffic model	full buffer
HARQ	none
Rank	1
Number of cells	21 (7 sites with 3 cells each), wrap-around
Number of UEs per cell	15
Number of drops	10
TTIs per drop	1000

Cell edge throughput = f(latency) @ same cell spectral efficiency



Cell edge throughput = f(latency) @ same alpha = 1.0



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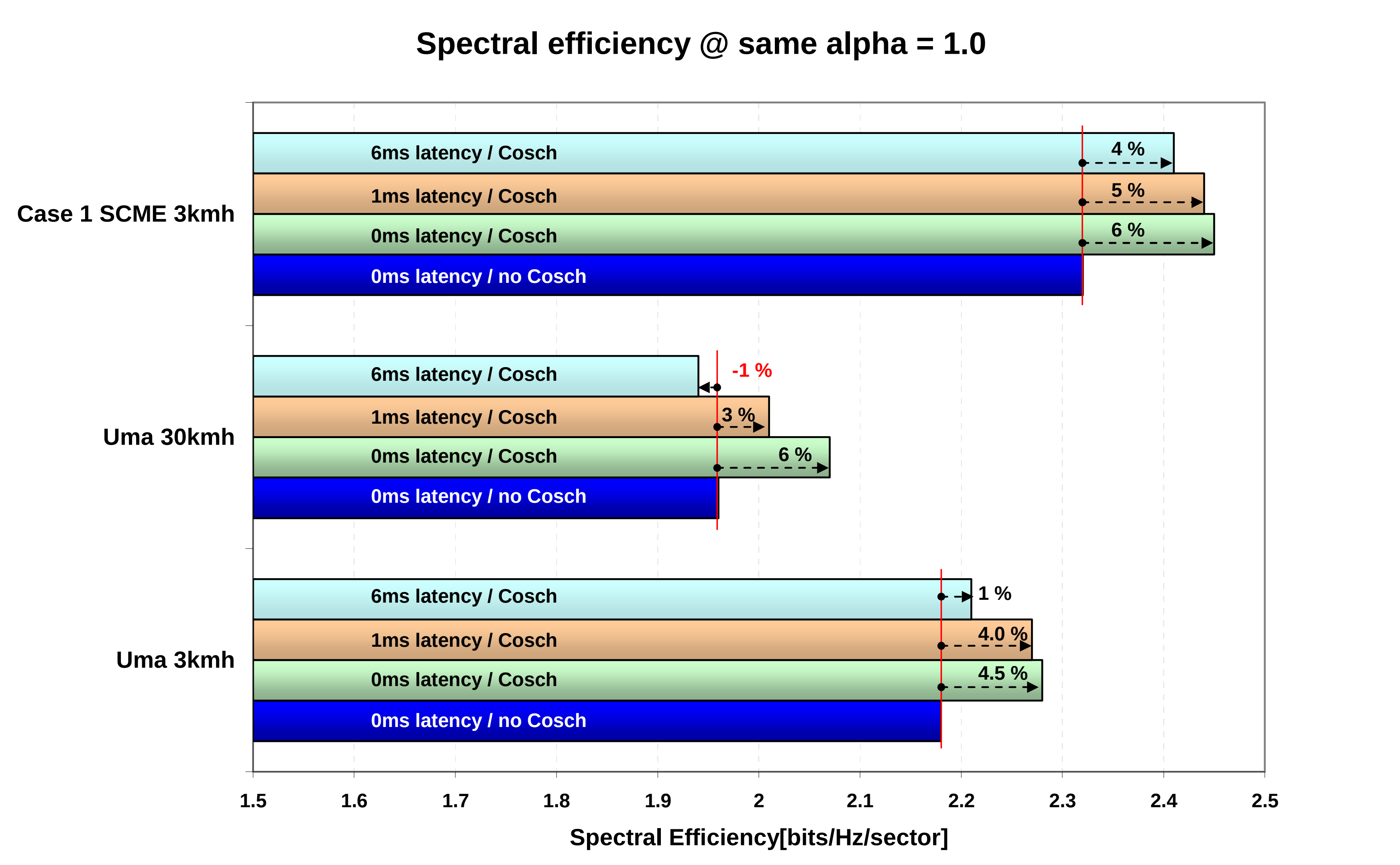

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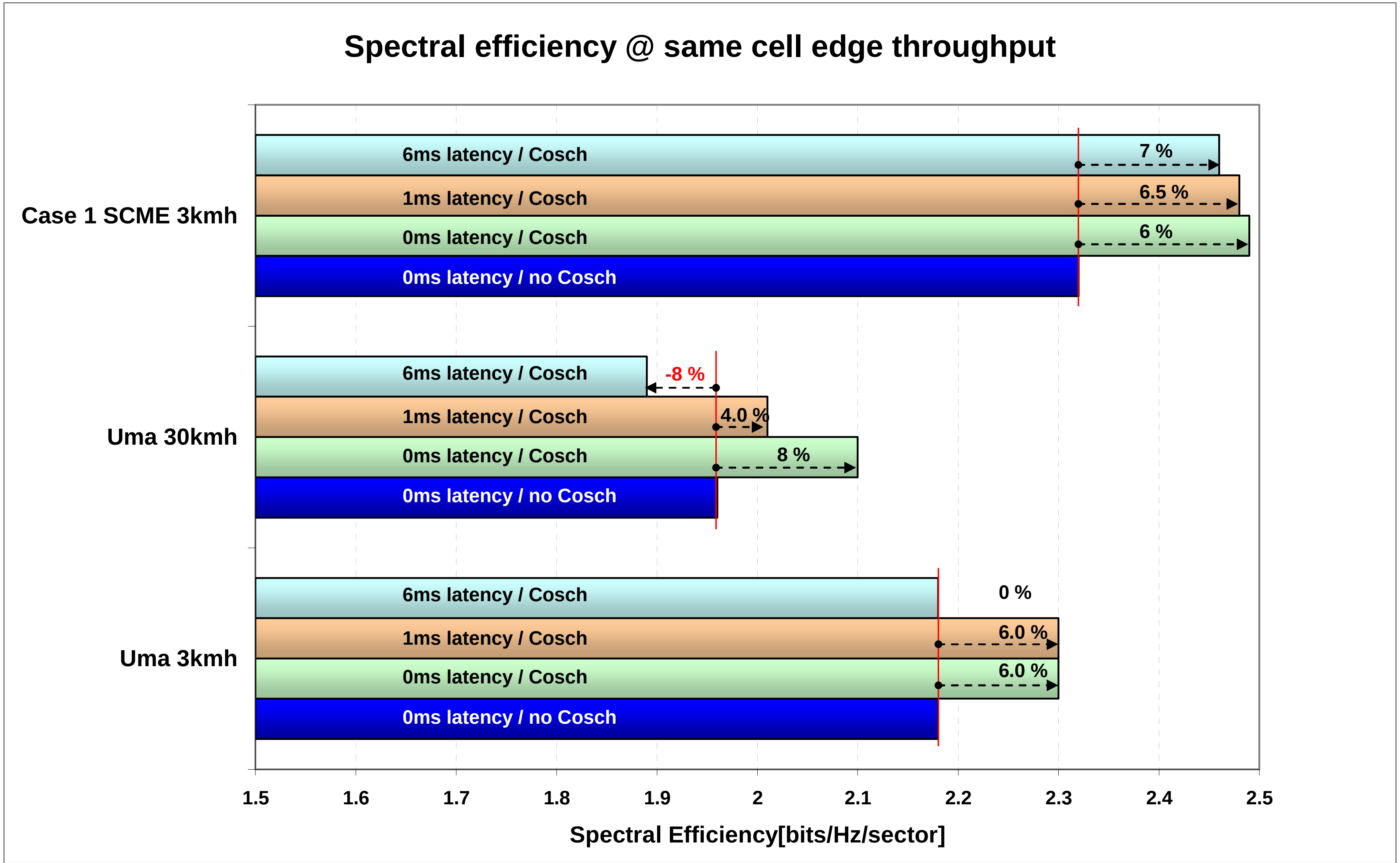
Spectral Efficiency = f(latency) @ same cell edge throughput



Conclusion

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Conclusion and Outlook

Coordinated scheduling by cyclic prioritization

- gain decreases with X2 latency
  - loosing frequency selective scheduling gain due to outdated channel info
  - no gain for ITU UMa around 5 ms, 3GPP SCME less sensitive
- gain increases with schedulable UEs per cell
  - probability to find a UE fulfilling all constraints increases
- limit constraints to 3 out of 8 PMIs (grid of beams w/ ULA-4V) covers most gain

Outlook

- CoSch + MU-MIMO, i.e. “worst” + “best” companion reporting combined
  - CoSch gain against MU-MIMO baseline
- more scenarios
  - X-pol. antennas (CLA-2X), 1732 m ISD (3GPP Case 3)

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