KEYFRAME INSERTION for Fast Channel Switching & Packet-Loss Repair in Low-Delay Live Streaming

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The GOP size trade-off

Very long GOP

✓ efficient **compression**

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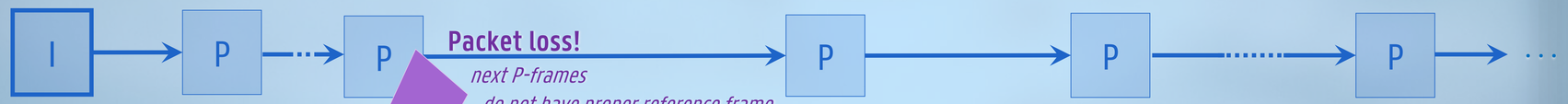

Packet loss!
next P-frames do not have proper reference frame

Channel switch!
need to wait a long time for keyframe

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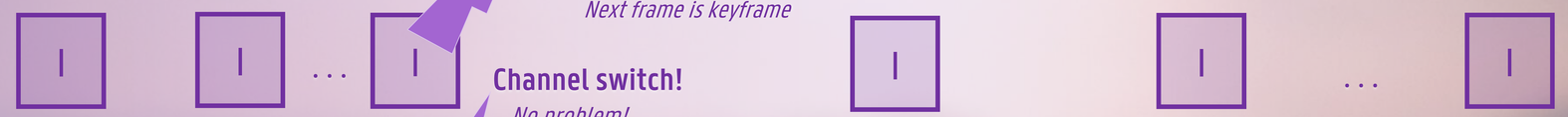

Packet loss!
No problem!
Next frame is keyframe

Channel switch!
No problem!
Next frame is keyframe

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Solution: Combine very long + very short GOP

Normal Stream (NS) *with very long GOP*

Companion Stream (CS) *with only keyframes*

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Steady-state users are **not impacted** by keyframe insertion of another user

I → P → P ⋯ **Packet loss!** → P → P → P ⋯

without CS, next P-frames do not have proper reference frame

P-frame now has CS **keyframe as reference**

it's not perfect, but better than no reference

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Sent **only to users when they need it**

I I ⋯ I

Channel switch!

without CS, need to wait a long time for keyframe in NS

Quick fix: keyframe inserted

only for this user!

I

Next CS keyframes **not transmitted** until needed again

I ⋯ I

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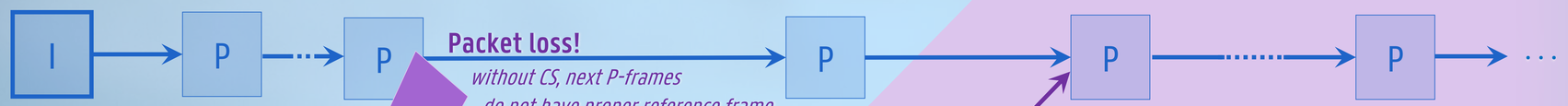

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Requirements

For H.264/AVC, H.265/HEVC & H.266/VVC

- ✓ Disable TMVP
- ✓ Repeat Packet Sets
  i.e., VPS, SPS, PPS & APS
- ✓ POC Keyframe = #0
  in practice, relaxed at decoder
  only in H.264/AVC & H.265/HEVC IDR

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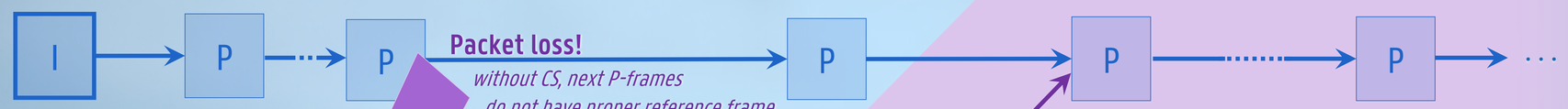

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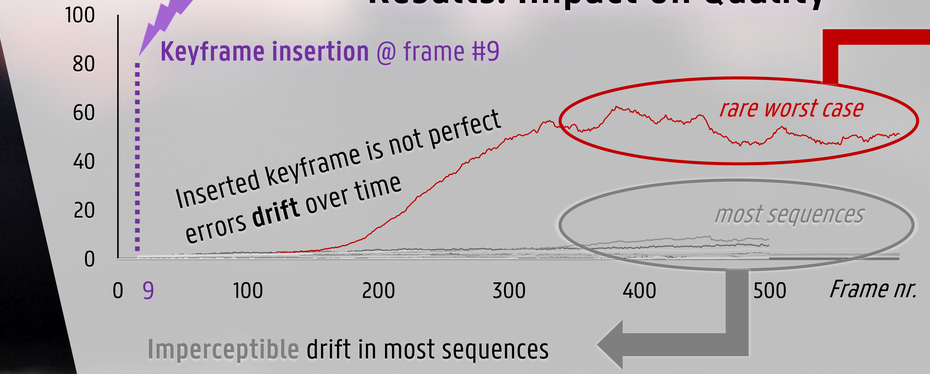
Results: Impact on Quality



Imperceptible drift in most sequences

0.14 ≤ median VMAF decrease ≤ 1.69 *(for equal QP in NS & CS)*

only when no new keyframe in NS for multiple seconds!

Perceptible drift in rare worst case

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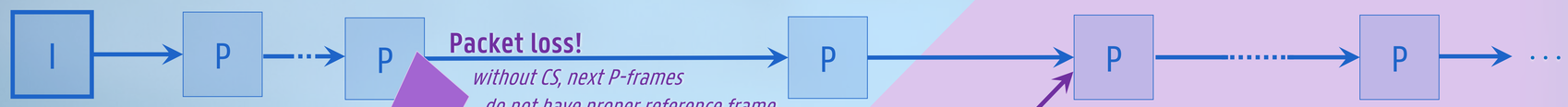

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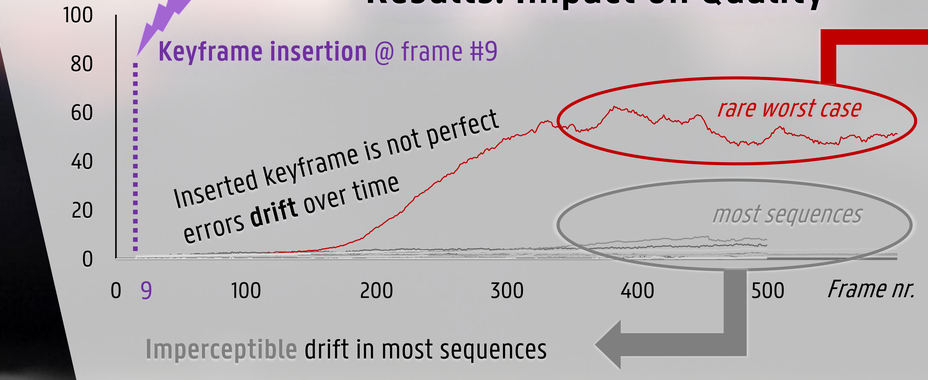

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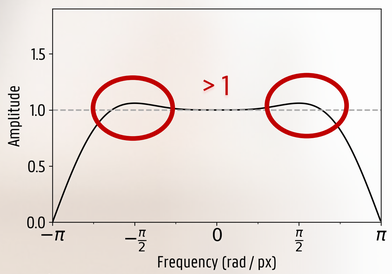

Fixed by **modifying interpolation** coefficients or **disabling subpel** motion estimation

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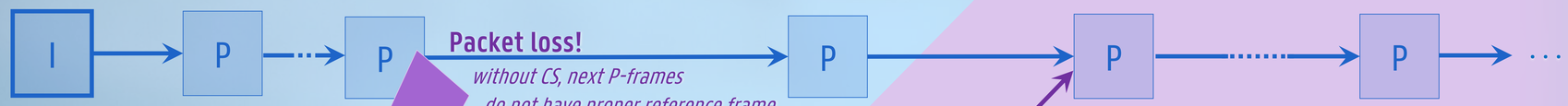

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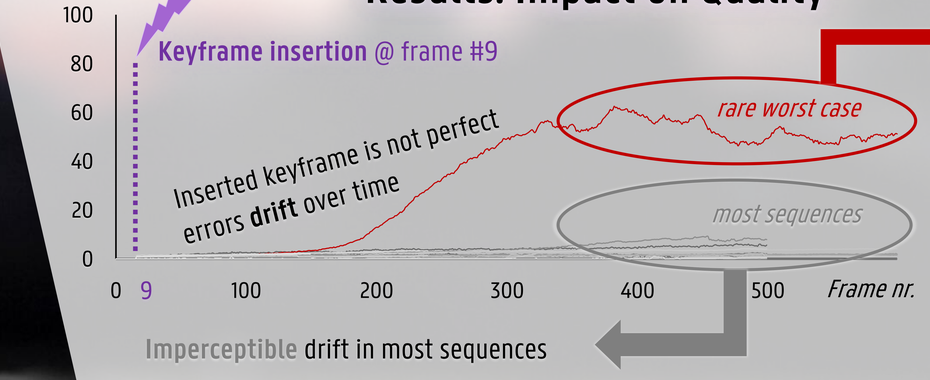

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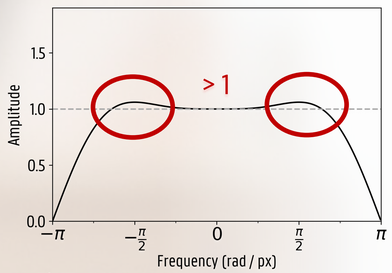

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Conclusion

TL;DR:

insert **keyframe** in **compression-efficient** stream
to **enable fast channel switching & packet-loss repair**
without impacting the performance of other users

- ✓ Generally **imperceptible**
- ✗ Sometimes **perceptible** artifacts in worst case
- ✓ **Fixed** by modifying or disabling subpel interpolation
  - Future work: fix differently

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