



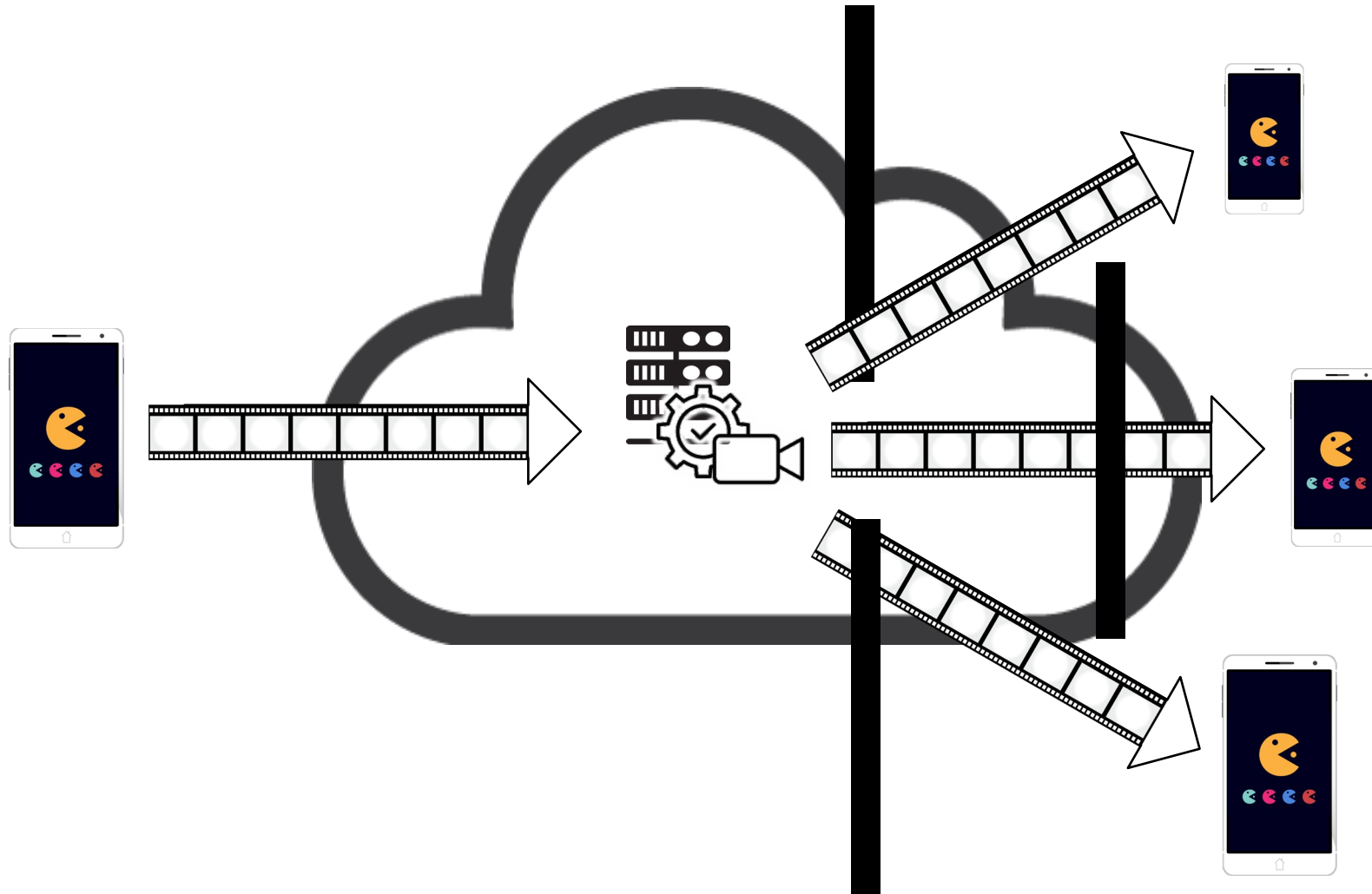
LevelUp: A Thin-cloud Approach to Game Livestreaming

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Game Livestreaming

- Twitch
 - Average >2m concurrent viewers and >90k concurrent channels
 - >65m hours streamed and >1.5b hours watched per month
- Market size \$40b, expected to grow 18% per year

Game Livestreaming

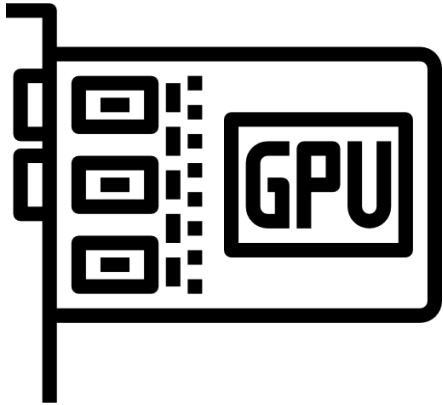


Cloud-based Video Transcoding Is Expensive

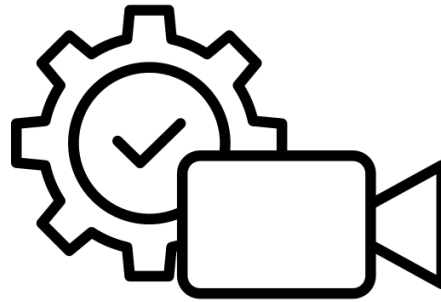
- \$300+ to transcode 100 hours of video on Azure
- <\$20 to livestream 100 hours of single-bitrate video on Wowza
- Reason: Video transcoding is resource demanding, usually requires hardware accelerators in the cloud

Mobile Hardware Trends

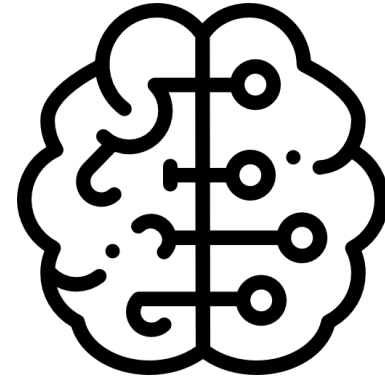
- The **edge** is ready to play a more **central role** in video livestreaming



GPU



video codec

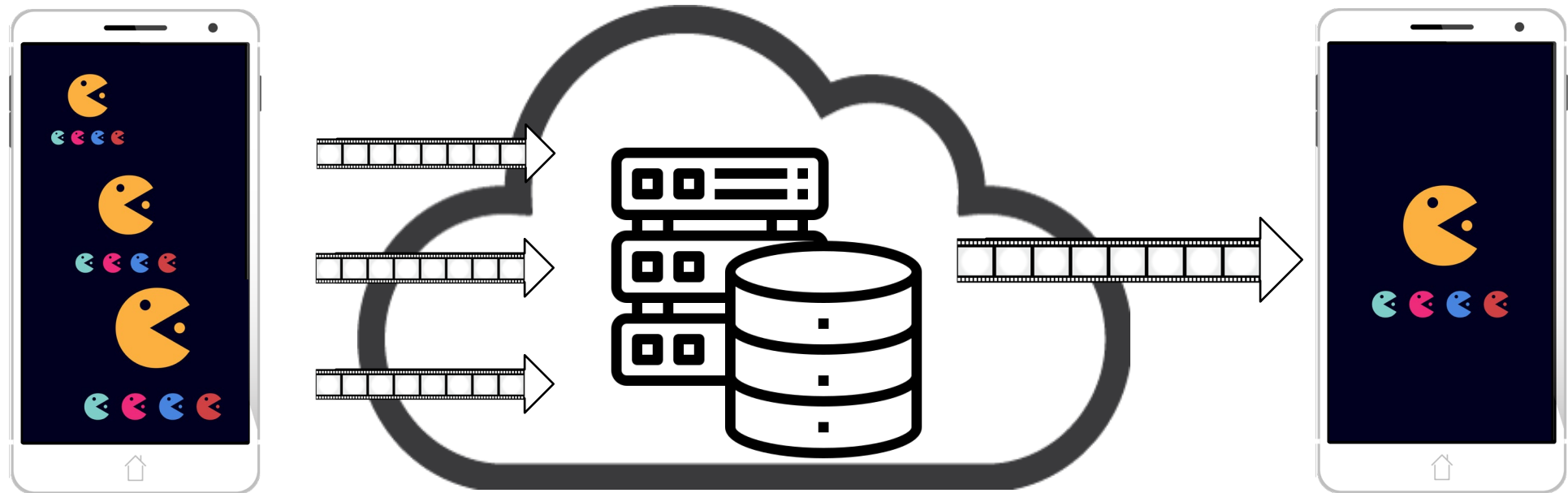


ML

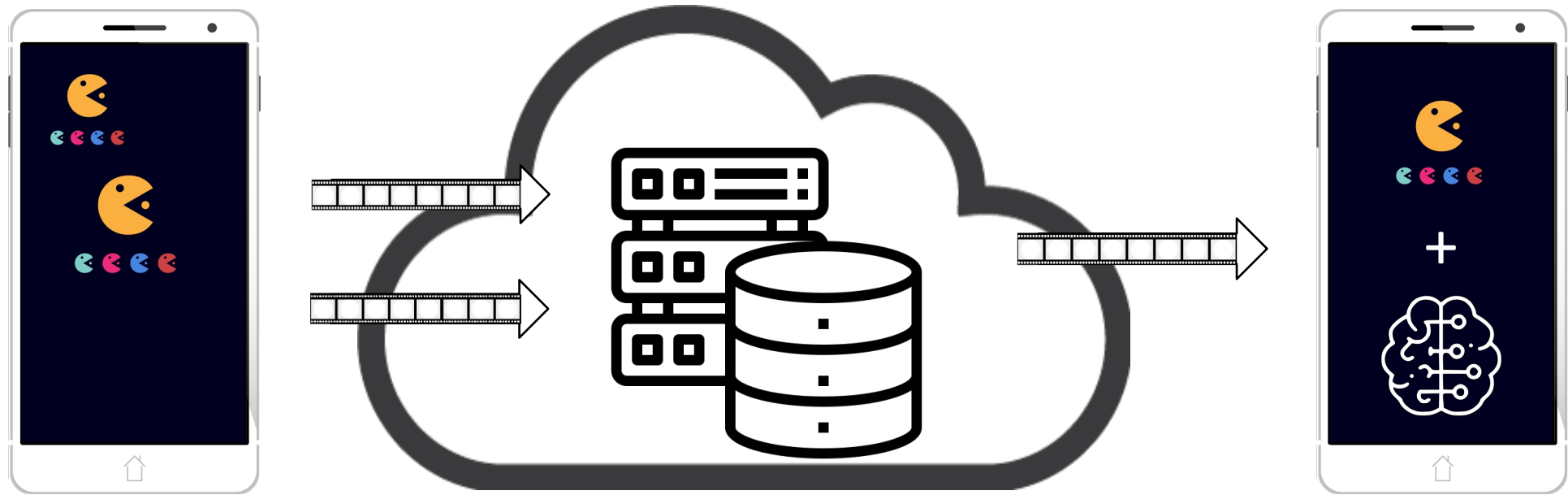
Overview of the paper

- Idea
 - Offload cloud-based transcoding by encoding multi-bitrate videos on **broadcasters' smartphones**
 - In case of bandwidth constraints, viewers boost reduced-resolution video quality with **super-resolution** using ML
 - Adopt **game-specific CNN models** to improve quality
- Contributions
 - Implementation of LevelUp prototype
 - Evaluation on COTS mobile devices
- Key Results
 - **88%** improvement for low-resolution game streams
 - Only **5%** battery usage for 30 mins video

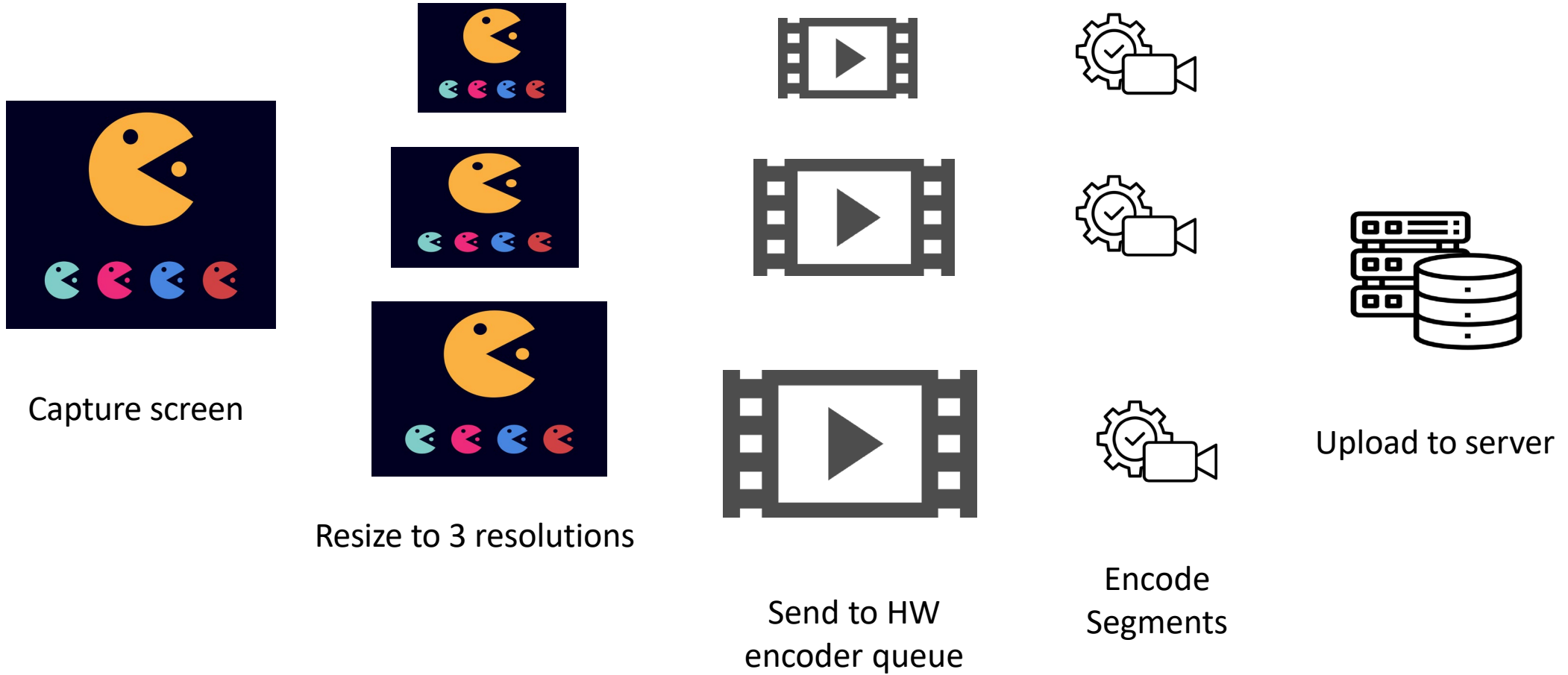
LevelUp Design



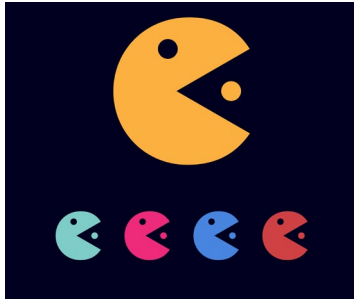
LevelUp Design – bandwidth constrained



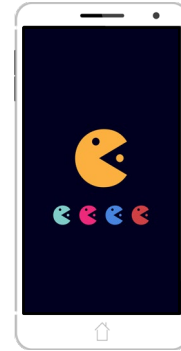
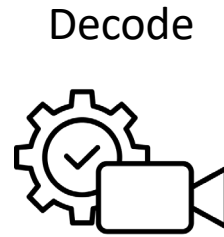
Broadcaster's video pipeline



Viewer's video pipeline – without SR



Download video segment



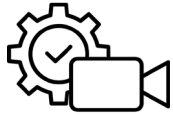
Display

Viewer's video pipeline – with SR

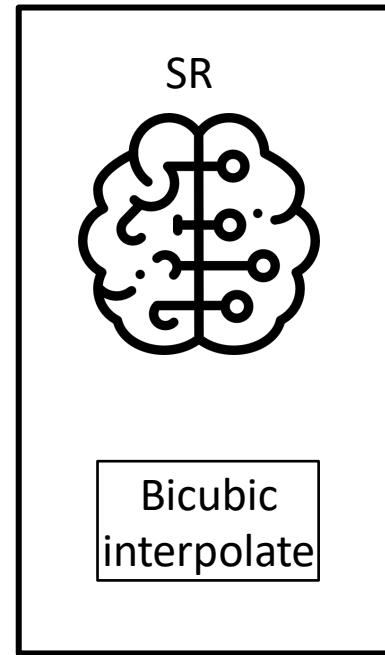


Download
video segment

Decode



Separate grayscale,
chroma



Merge,
display

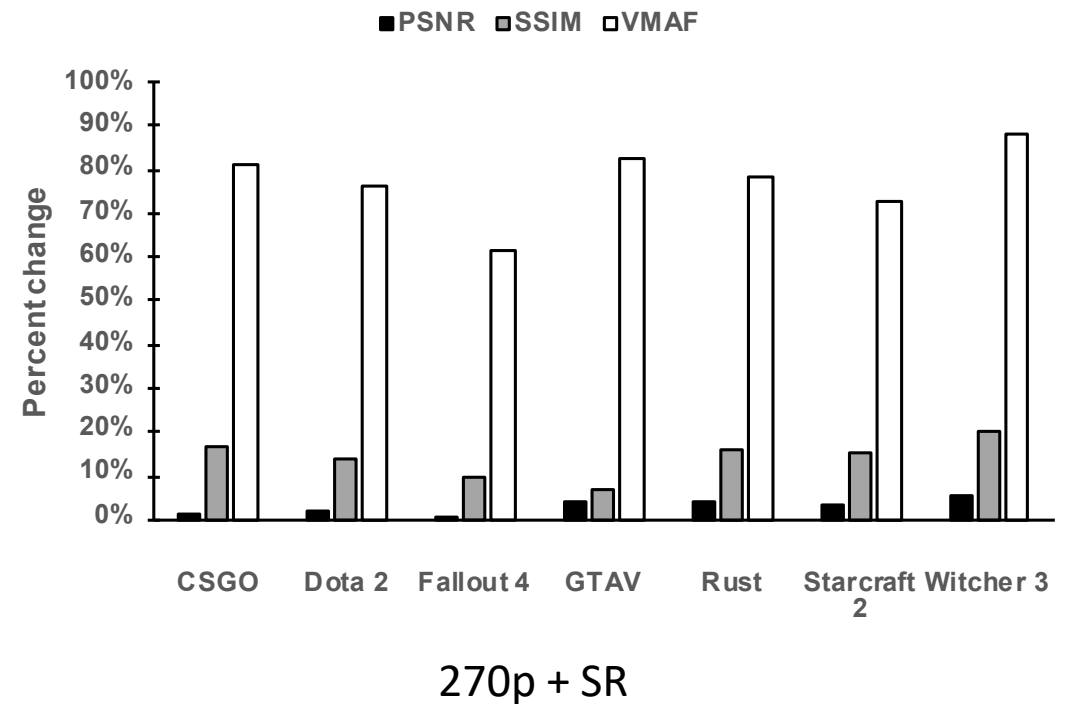
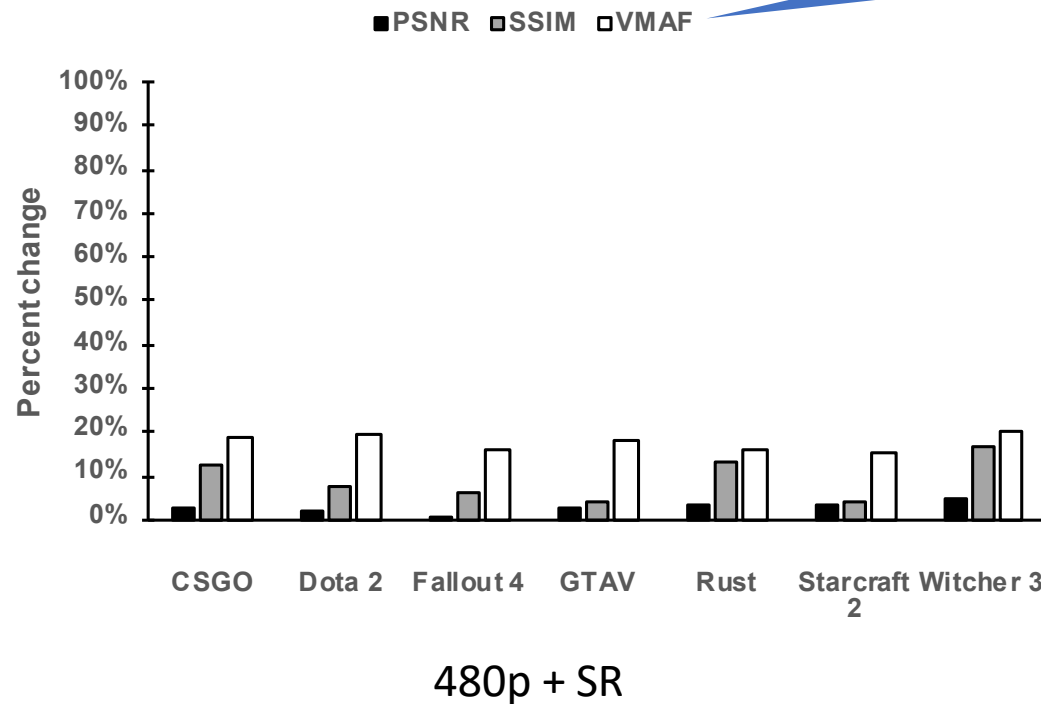
How it builds on previous works

- Incremental work on DNN-based video super resolution (e.g., NAS)
- Similar to Dejavu which is used for video conferencing
- Orthogonal to other advances in codecs, compression, bitrate adaption

Game stream super-resolution

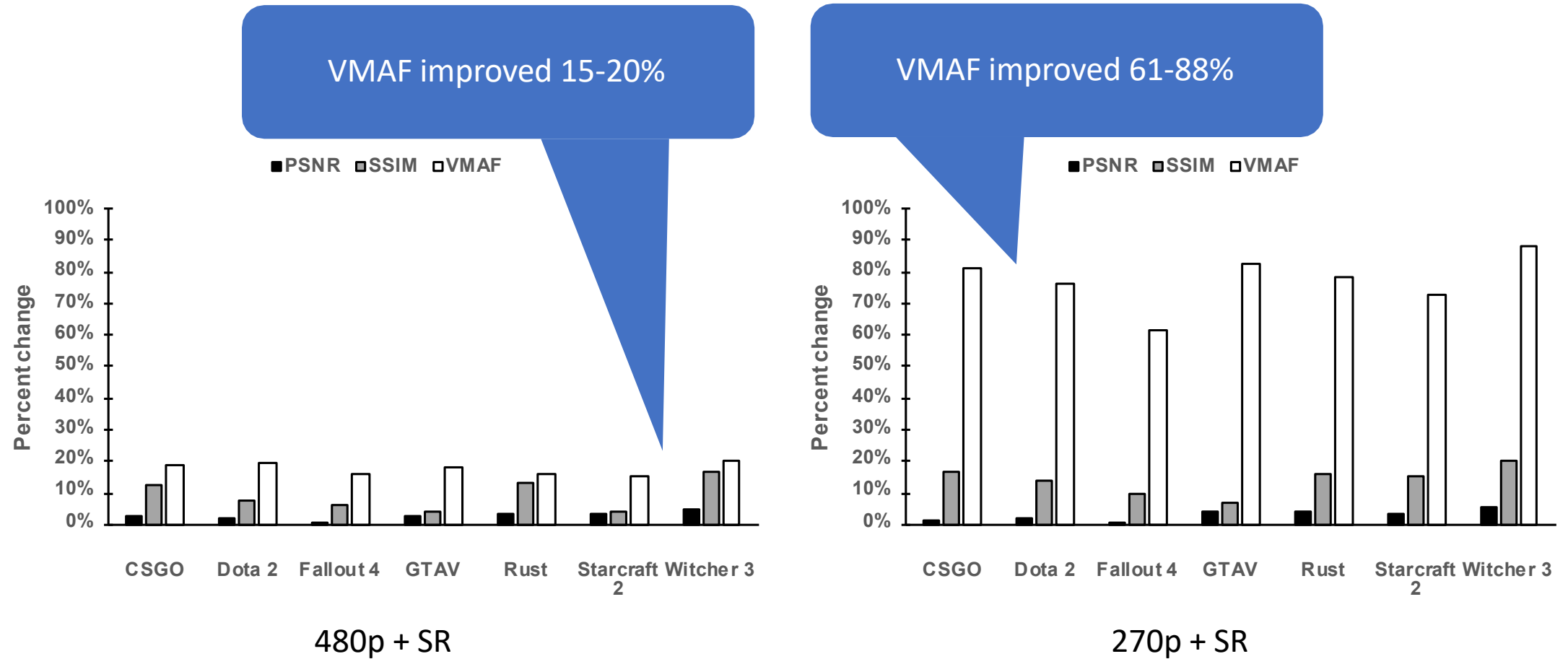
of improvements with SR

PSNR: per-pixel, SSIM: structural,
VMAF[1]: ML model of human perception



[1] <https://github.com/Netflix/vmaf>

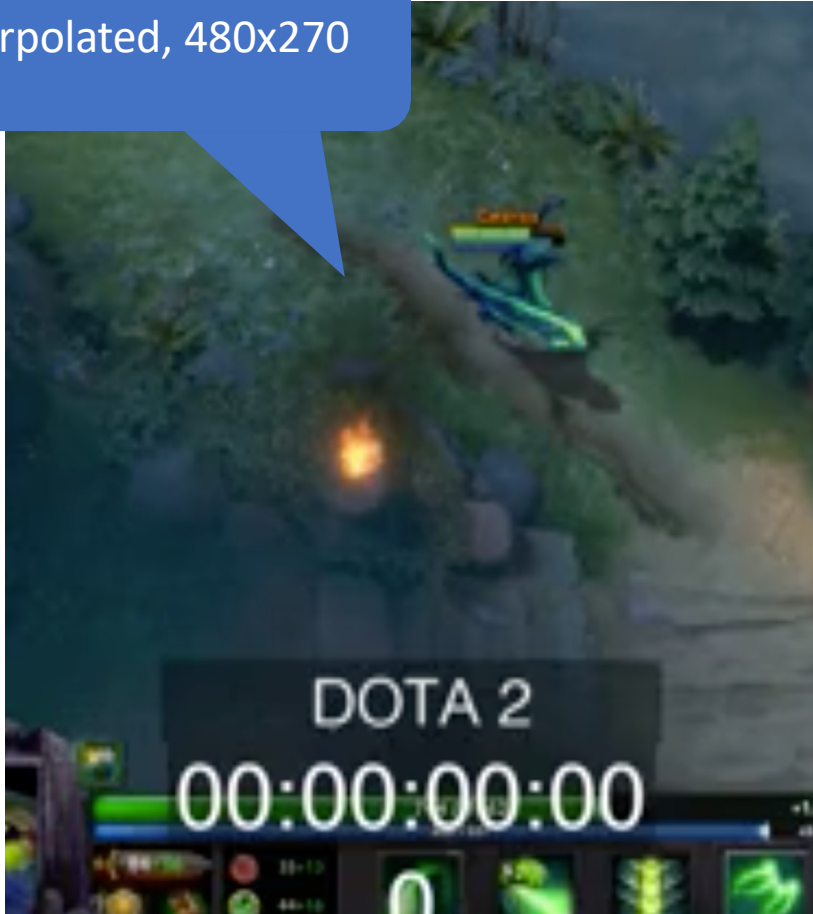
Game stream super-resolution



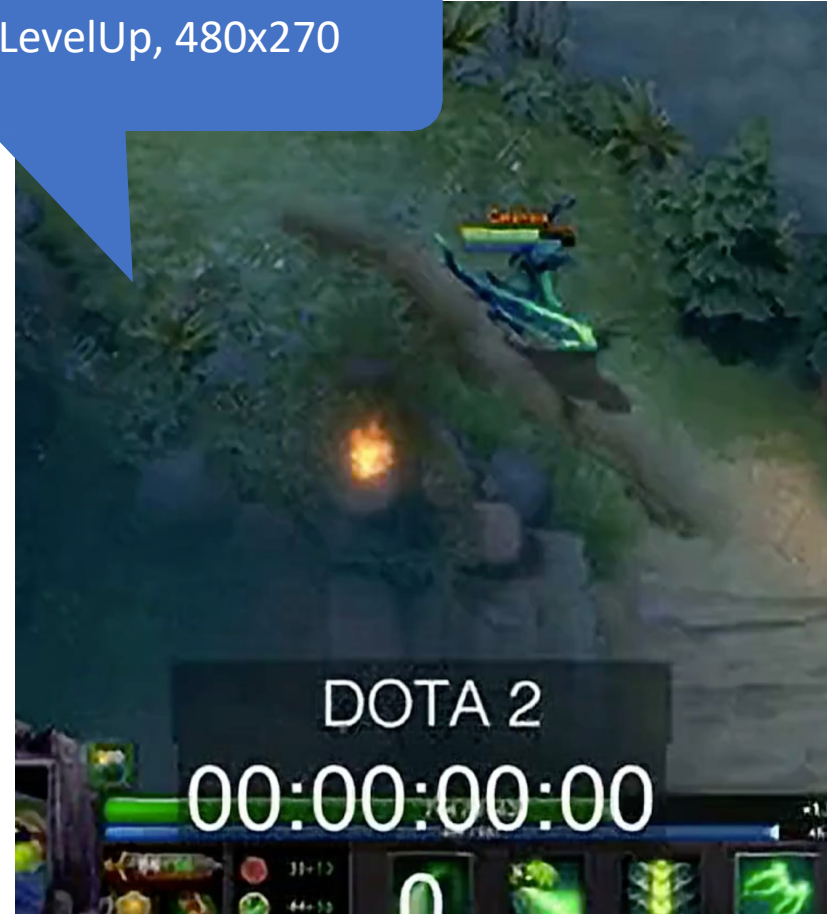
[1] <https://github.com/Netflix/vmaf>

Game stream super-resolution

Interpolated, 480x270

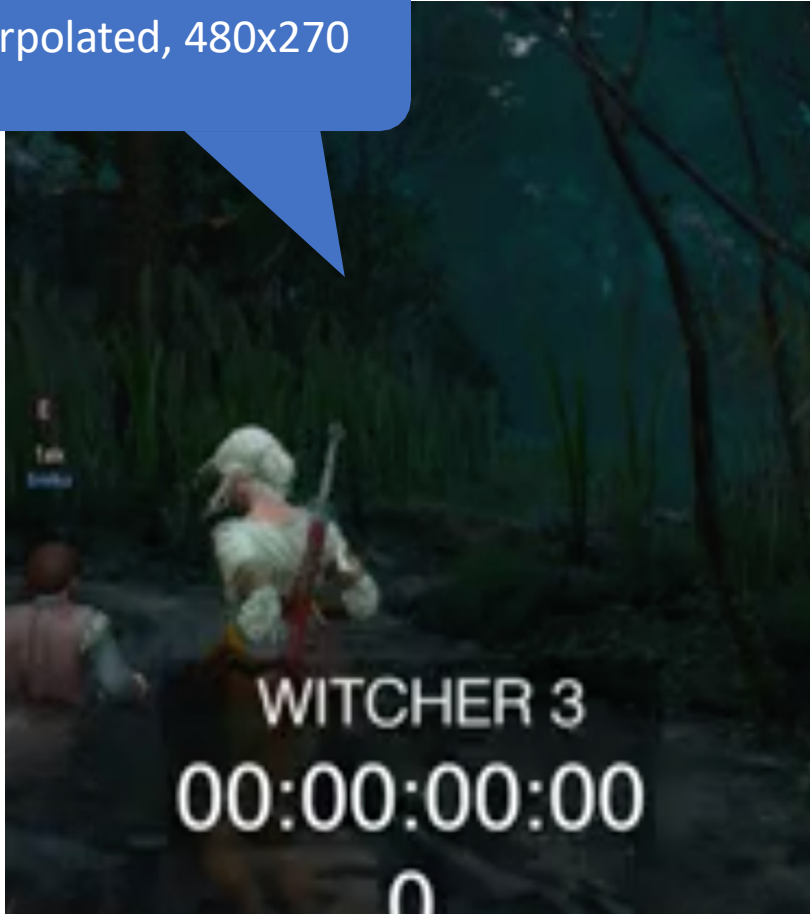


LevelUp, 480x270

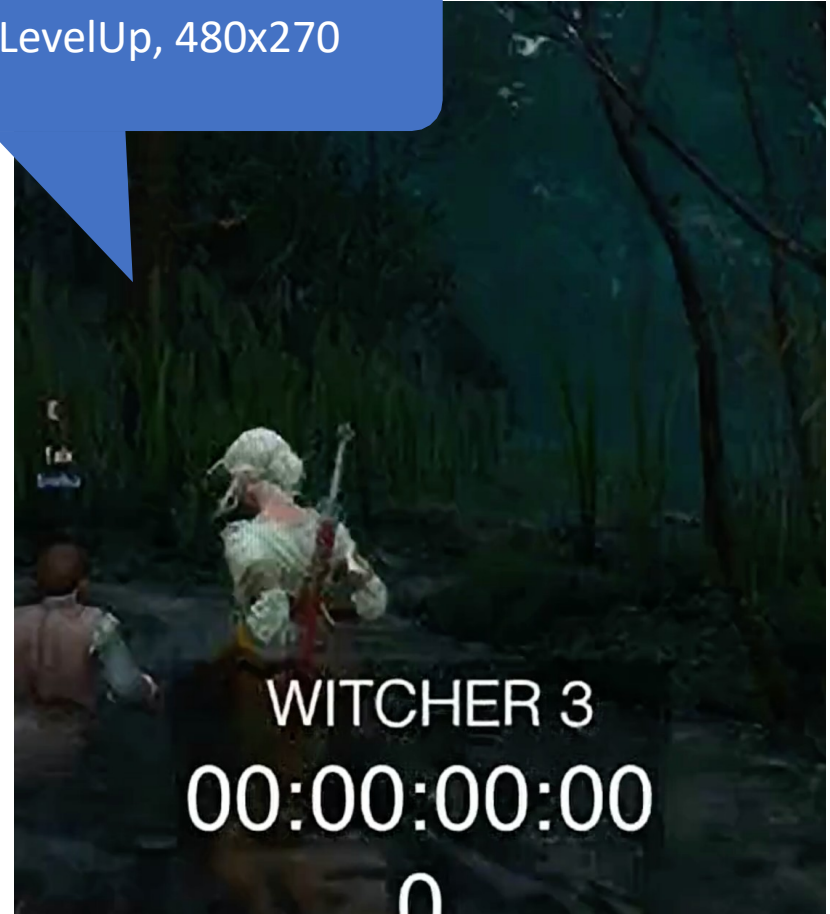


Game stream super-resolution

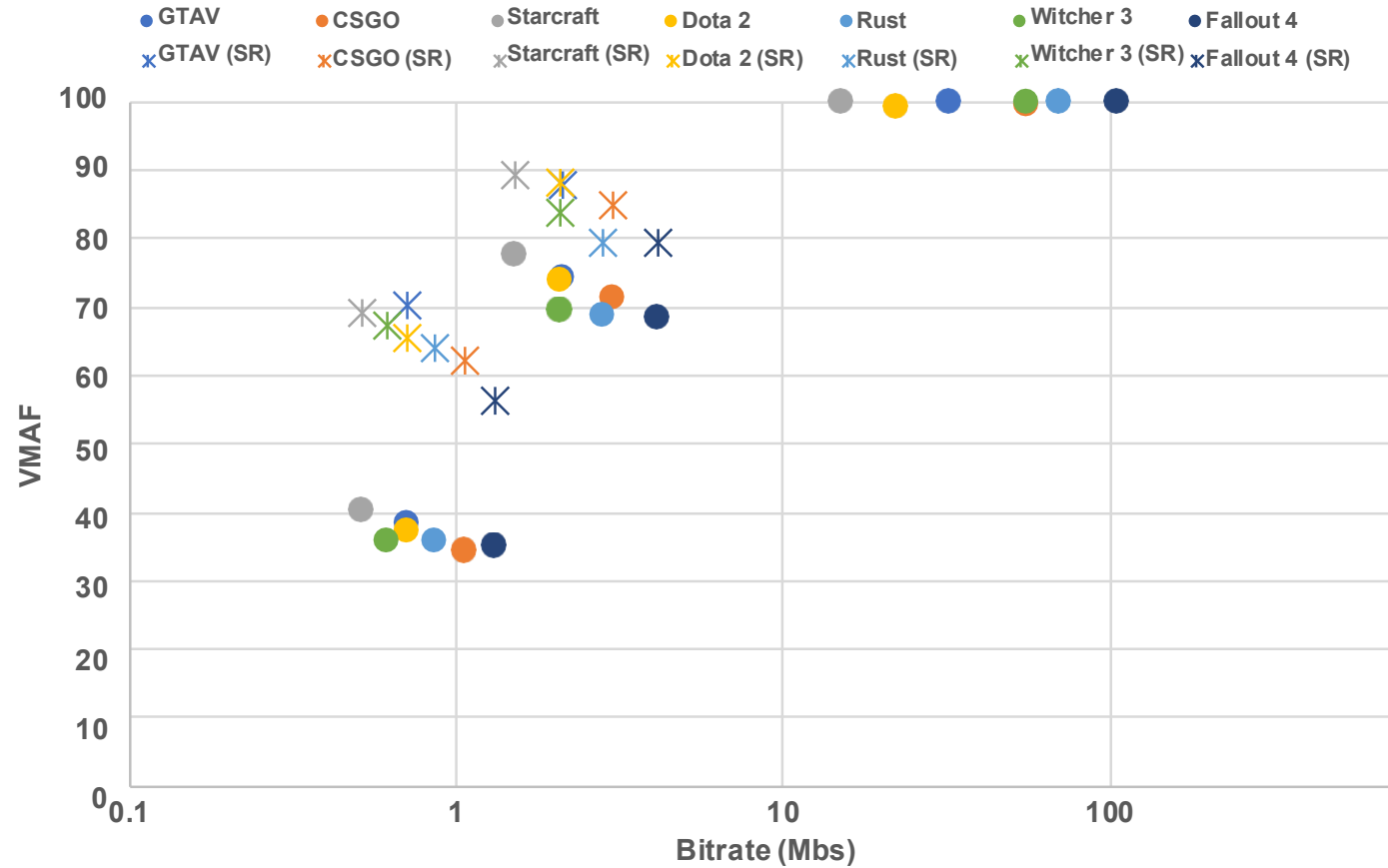
Interpolated, 480x270



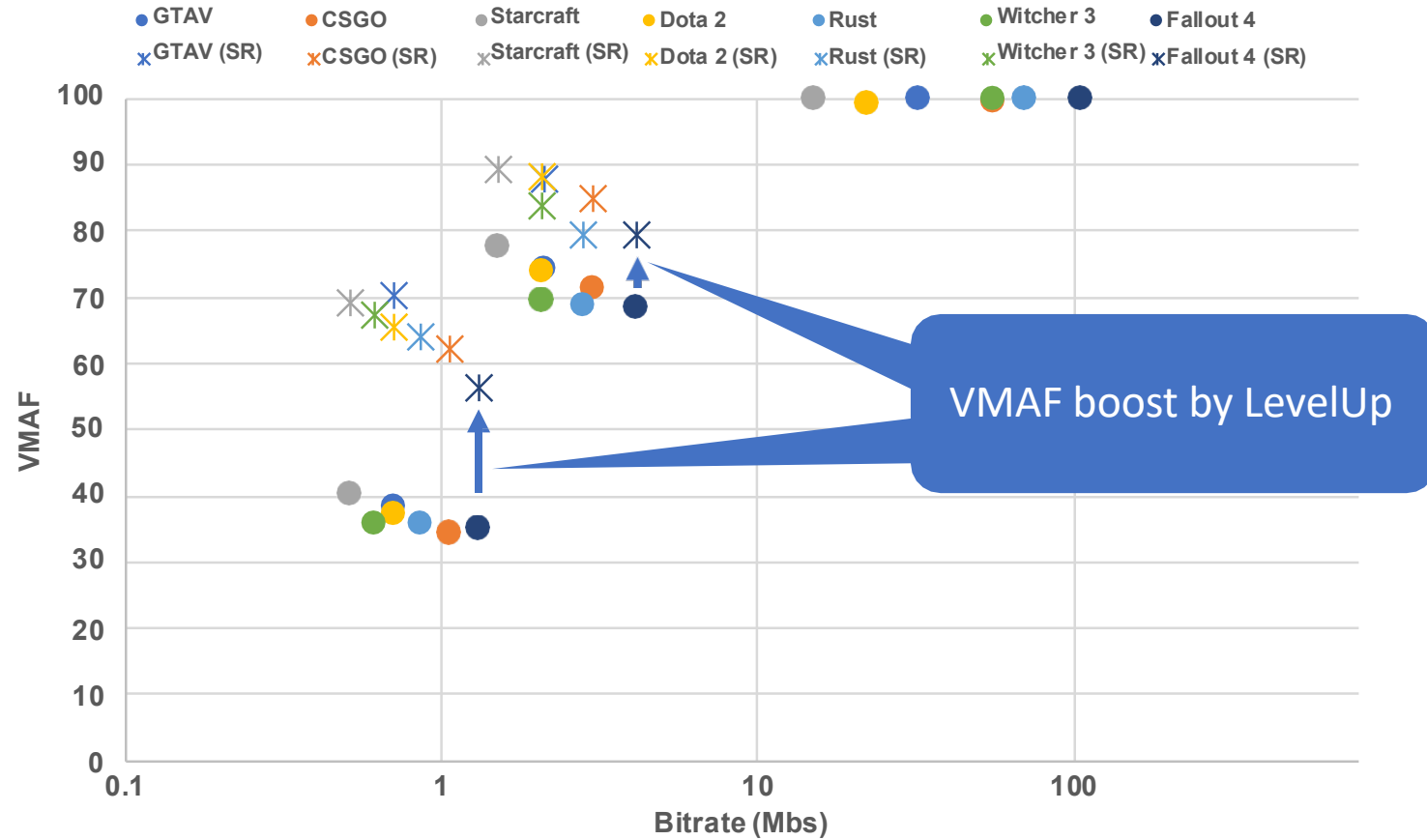
LevelUp, 480x270



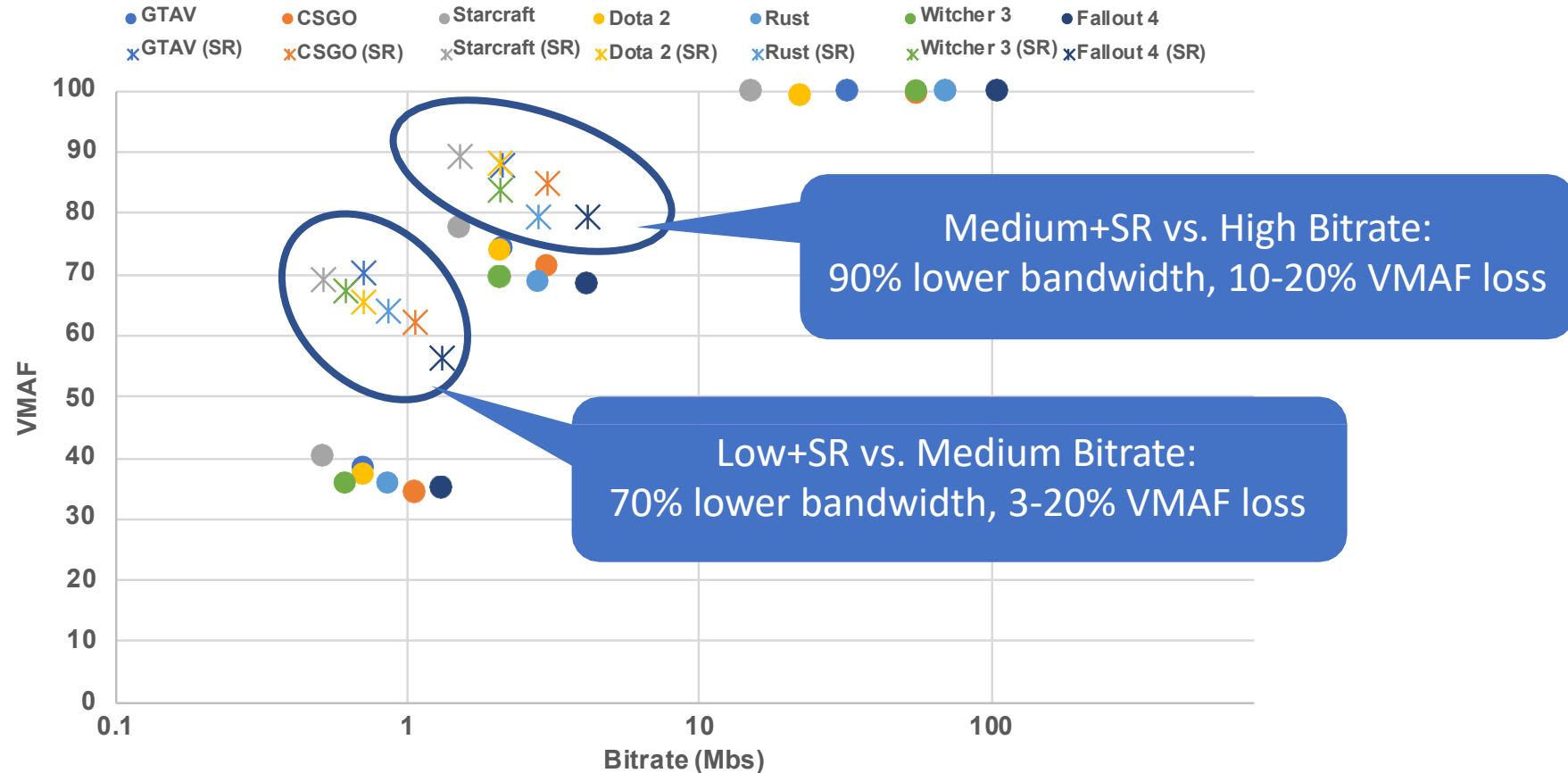
Quality vs. Bitrate



Quality vs. Bitrate



Quality vs. Bitrate

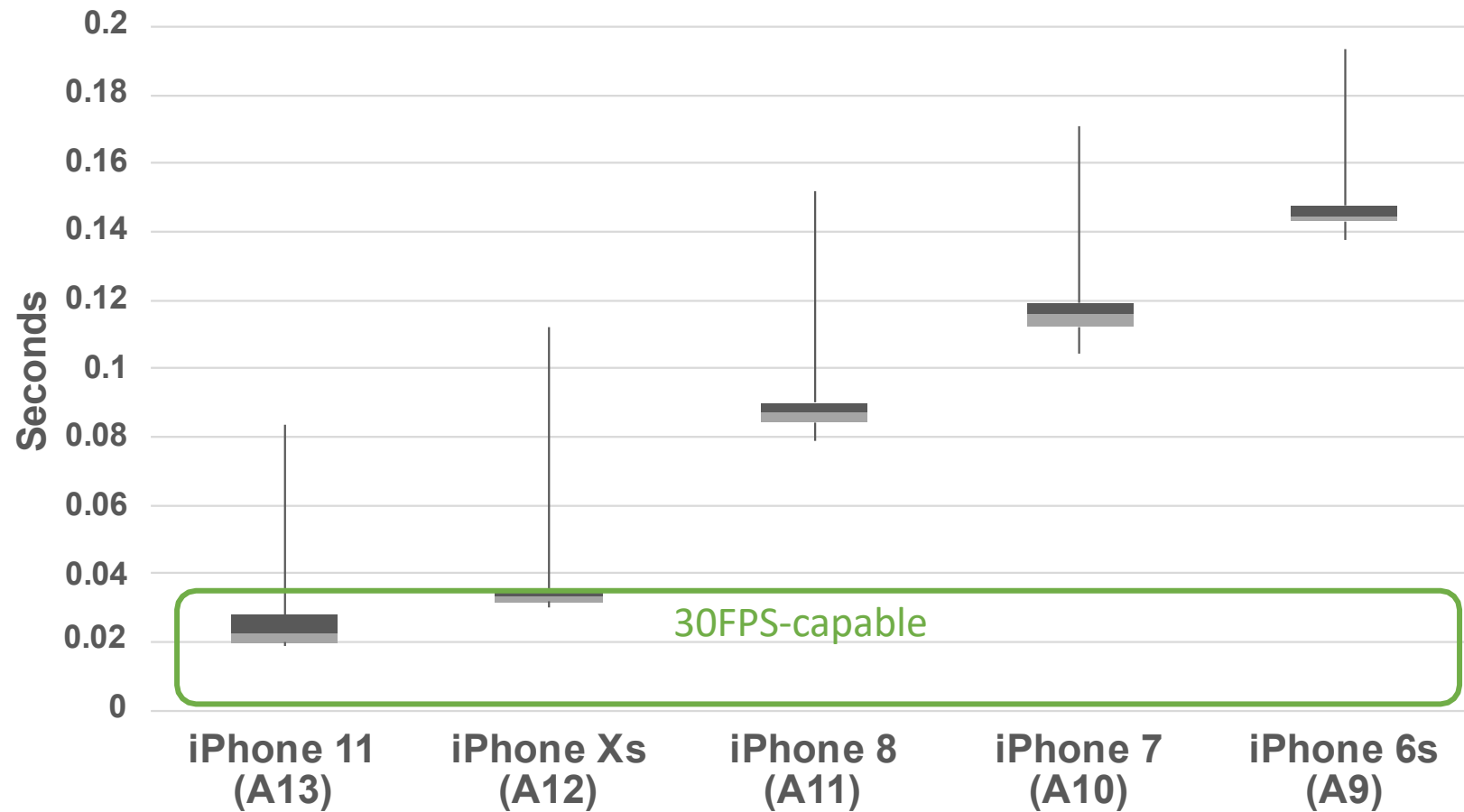


Super-resolution can greatly improve game stream quality w/o extra bandwidth consumption

Can broadcaster encode multi-bitrate streams?

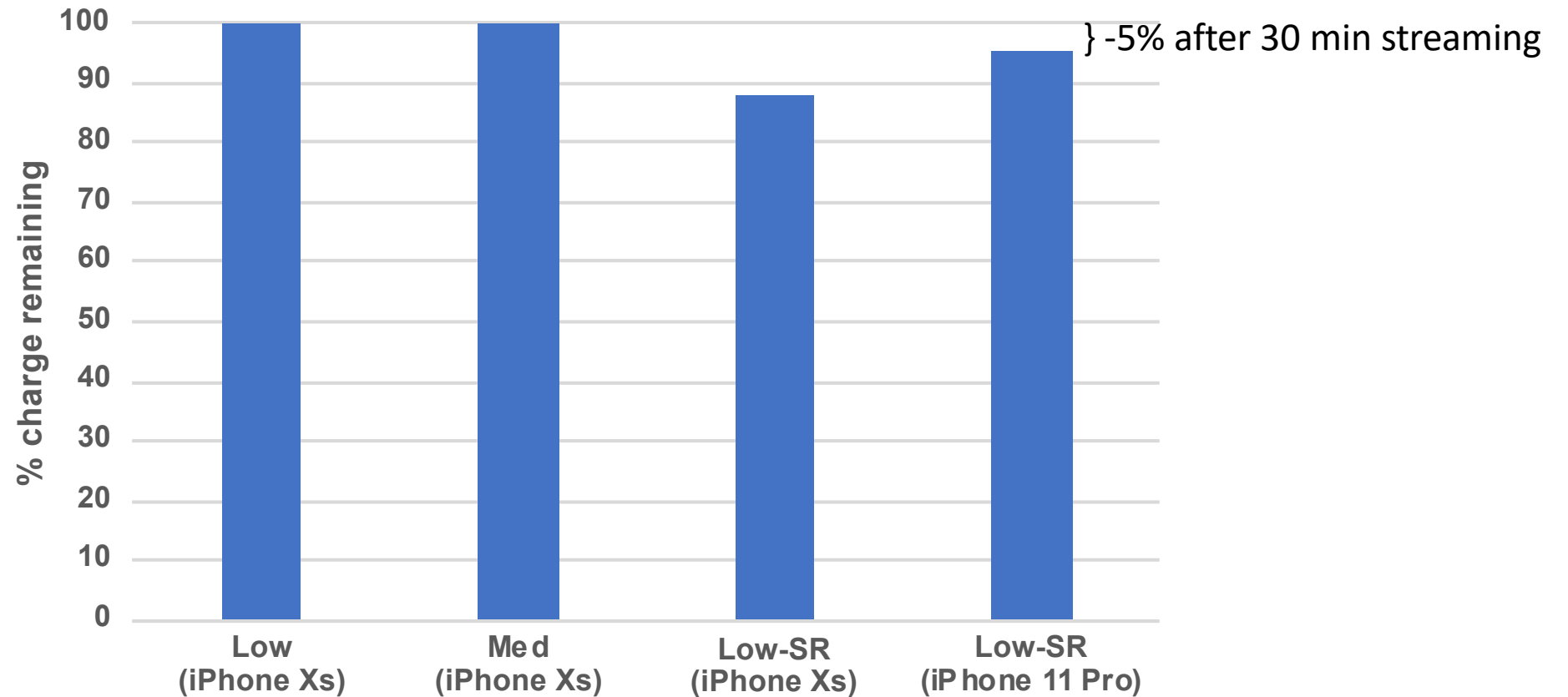
- Encode 3 2-second segments (1080p, 480p, 270p) at the same time
- Test on iPhone 11 Pro, the iPhone Xs, iPhone 8, iPhone 7, and iPhone 6s
- All devices can encode in realtime
- Multi-bitrate encoding is feasible on modern smartphones

Can viewers super-resolve video?



Recent smartphones equipped with ML accelerators can super-resolve gaming streams in realtime.

Energy overhead



LevelUp has small energy overheads even with super-resolution enabled.

Conclusion

- Game livestreaming is **expensive** due to realtime transcoding
- LevelUp can **greatly reduces** game livestreaming costs by leveraging smartphones for transcoding
- LevelUp uses **super-resolution** to boost quality for reduced-resolution videos by up to 88%
- LevelUp can transcode and super-resolve game streams **in realtime** using recent smartphone hardware accelerators

Discussion

- Strengths
 - Clean and novel approach
 - Evaluation is extensive and relevant
 - Tradeoffs are well studied
- Weaknesses
 - Too much background information
 - System should be hybrid: cloud can still be helpful
 - Simple cost analysis could be included
 - Mobile bandwidth and resources are costly