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

GPU
video codec
ML
Mobile Hardware Trends

- As of May 2018, hundreds of millions devices equipped with powerful GPU/hardware codec/ML accelerators
- Most smartphones are expected to have ML accelerators in few years
- Combined capabilities of hardware accelerators on mobile devices are greater than the cloud

- The edge is ready to play a more central role in video livestreaming
**LevelUp**: A Thin-cloud Approach to Game Livestreaming

- 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
LevelUp Design

What if bandwidth is not enough?
LevelUp Design – bandwidth constrained
Single-image super resolution (SR)

- CNNs **upscale resolution** of reduced-resolution images
- Mobile **ML accelerators** enable fast NN computation
- A lightweight CNN model of **4 layers** is sufficient for LevelUp
- Different games have visual features, require different models
- Models are trained offline, downloaded to viewers before streaming
Broadcaster’s video pipeline

Capture screen

Resize to 3 resolutions
Send to HW encoder queue

Encode segments

Upload to server
Viewer’s video pipeline – without SR

Download video segment

Decode

Display
Viewer’s video pipeline – with SR

Download video segment

Decode

Bicubic interpolate

Separate grayscale, chroma

Merge, display
Evaluation

• Can super resolution improve the visual quality of reduced-resolution game streams?
• Can broadcasters perform multi-bitrate encoding in realtime?
• Can viewers super-resolve reduced-resolution video streams in realtime?
• What is LevelUp’s energy overhead?
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

- **VMAF improved 15-20%**
  - PSNR
  - SSIM
  - VMAF

- **VMAF improved 61-88%**
  - PSNR
  - SSIM
  - VMAF

Percent change

- **480p + SR**

- **270p + SR**

[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

VMAF boost by LevelUp
Quality vs. Bitrate

Low+SR vs. Medium Bitrate: 70% lower bandwidth, 3-20% VMAF loss

Medium+SR vs. High Bitrate: 90% lower bandwidth, 10-20% VMAF loss

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.

{ }-5% after 30 min streaming
Conclusion

• Game livestreaming is expensive due to realtime transcoding
• LevelUp can greatly reduce 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
Thank you!

Q & A

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