Vantage
Optimizing video upload for time-shifted viewing of social live streams
(SIGCOMM 2019)

Devdeep Ray, Jack Kosaian, Rashmi Vinayak, Srinivasan Seshan

Carnegie Mellon University
Social live video streaming (SLVS)
Challenges in mobile social live streaming

Limitations of current techniques

Vantage:

Key ideas

Design and implementation

Evaluation
Network impairments tolerated by real-time viewers
Charlie
(Attending SIGCOMM during concert)
One Eternity Later
Delayed viewers also affected by network impairments
Typical SLVS platforms today
Video upload path is critical

Mobile streaming common

Significant bandwidth variation on upload path

The uploaded video is a baseline for all viewers

Downstream optimizations are limited by upload quality
Live video streaming today

Social live streaming has both real time and delay-tolerant viewers for the same session
SLVS applications use conferencing techniques
SLVS today: Same video quality for all viewing delays
Goal: Better quality for delayed viewers

Goal: SLVS applications
Challenges in mobile social live streaming

Limitations of current techniques

Vantage:

Key ideas

Design and implementation

Evaluation
Existing upload techniques: Real-time streaming

Conferencing
(Skype, Hangouts, ..)

"Real-time" latency constraints

Bitrate closely matches available bandwidth

Sensitive to bandwidth variation

Available bandwidth

Video encoding bitrate

Bob (Real-time)
Charlie (Delayed)
Existing upload techniques: Buffered streaming

**Broadcasting**
(Entertainment, News, ..)

Delay tolerant

Encode at ~ average bandwidth

Large sender-side buffers to absorb bandwidth variation

Higher video quality, no interactivity
Existing upload techniques

Inadequate for SLVS:
Delayed + high quality video
OR
Interactive video
Challenges in mobile social live streaming

Limitations of current techniques

Vantage:

Key ideas

Design and implementation

Evaluation
Observation #1: Bandwidth is highly variable

Analyzed traces from the Mahimahi ** project

Significant variations observed, with extreme lows and highs

Catering to multiple viewing delays

**Network is impaired:** Use real-time strategy

**When network recovers:** Use less than capacity for real-time

Excess bandwidth used to repair past segments
Viewing quality for different delays

Real-time video bitrate

Available bandwidth

Real-time viewing video bitrate

Bob

Available bandwidth

Delayed viewing video bitrate

Delayed video bitrate

Charlie
Viewing quality for different delays

Why is Bob (real-time viewer) okay with this?
Aside: Video quality metrics

Video bitrate != video quality

Vantage uses SSIM for measuring perceived video quality

SSIM = 1.0

SSIM = 0.66
Observation #2: Quality vs. Frame size is concave

Video encoded multiple times at different bitrates

Size vs. SSIM plot for each frame
Observation #2: Quality vs. Frame size is concave
Observation #2: Quality vs. Frame size is concave
Observation #2: Quality vs. Frame size is concave

Using high bandwidth to improve low quality frames very powerful!
Challenges in mobile social live streaming

Limitations of current techniques

Vantage:

Key ideas

Design and implementation

Evaluation
Vantage: System architecture

- **Record**: Mobile device
- **Upload**: Data transmitted to the server
- **Server**: Centralized processing
- **Real-time delivery**: Immediate access
- **Delayed delivery**: Data available after processing

Diagram:
- Mobile device connected to the server via upload
- Server connected to a laptop
- Two pathways: real-time delivery and delayed delivery
Vantage: Streamer Architecture

- Real-time encoder
- High quality storage
- Secondary encoder

Network
Vantage: Key challenges

Real-time decisions that optimize video quality for all viewing delays

Real-time video stream bitrate

Enhancement frame selection

Video enhancement stream bitrate
Input:
1. Bandwidth estimates
2. Frame encoding stats
Input:
1. Bandwidth estimates
2. Frame encoding stats

Output:
1. Real-time bitrate
2. Enhancement frames
3. Enhancement bitrate
Scheduling goals

1. Constrain encoded bits to the available bandwidth
2. Optimize video quality across multiple viewing delays
Vantage scheduler

Mixed integer program (MIP) maximizes quality for multiple viewing delays

Periodically generates video encoding schedule

Key challenges:

 Handling stale bandwidth estimates

 Mapping frame sizes to quality
Scheduler period trade-offs

Short time period

Accurate bandwidth estimates

Short sighted scheduling

Long time period

Stale bandwidth estimates

Long term optimal scheduling
Handling stale network estimates

Dual approach: Long term (MIP) + short term (Execution engine)

Vantage: MIP generates schedule every 2 seconds

Fallback strategy: Execution engine prioritizes real-time
Vantage scheduler

Mixed integer program (MIP) maximizes quality for multiple viewing delays
Periodically generates video encoding schedule

Key challenges:

Handling stale bandwidth estimates

Mapping frame sizes to quality
Frame size vs SSIM estimation

Frame size vs SSIM curve needed for optimization

Statistics from encoders drive estimation

Simple non-linear model: works well

Size vs. SSIM plot for each frame
Challenges in mobile social live streaming
Limitations of current techniques

Vantage:

Key ideas
Design and implementation

Evaluation
Vantage: Evaluation

Designed to work with existing congestion control protocols for real-time video

Emulated transport layer that provides network estimates from traces

Evaluation performed on different combinations of videos and network traces

Videos: Animated, talking head, drone footage

Network traces: LTE (Verizon, ATT), UMTS (T-Mobile) **

Baseline: Real-time (conference style) streaming

All viewers affected by network variations
Baseline: Buffered streaming

High quality for delayed viewing

Real-time viewing infeasible
Vantage: Quality enhancing retransmissions

Real-time quality almost as good as real-time baseline

Real-time baseline

Vantage
Vantage: Quality enhancing retransmissions

Real-time quality almost as good as real-time baseline

Delayed viewing quality significantly better!
Other results in the paper

Multiple traces + videos, detailed results in paper

Varying delay distributions

Sensitivity analyses of optimizer period and bandwidth estimation error

Ablation studies comparing Vantage with naive solutions
Results summary

Up to 42.9% (average 19.9%) higher delayed video quality
(Charlie = Happy)

At most 7% (average 3.3%) drop in real-time quality
(Bob = Still Happy)
Summary

SLVS applications present new and unique challenges

New paradigm of watching videos: Time-shifted viewing

Upload path variability is important to address

Vantage: Mitigates upload path variability to improve quality for time-shifted viewing

Thank you for listening!
Our research group

Devdeep Ray
devdepr@cs.cmu.edu

Jack Kosaian
jkosaian@cs.cmu.edu

Rashmi Vinayak
rvinayak@cs.cmu.edu

Srinivasan Seshan
srini@cs.cmu.edu