A Delay Recovery Phase For RMCAT Flows

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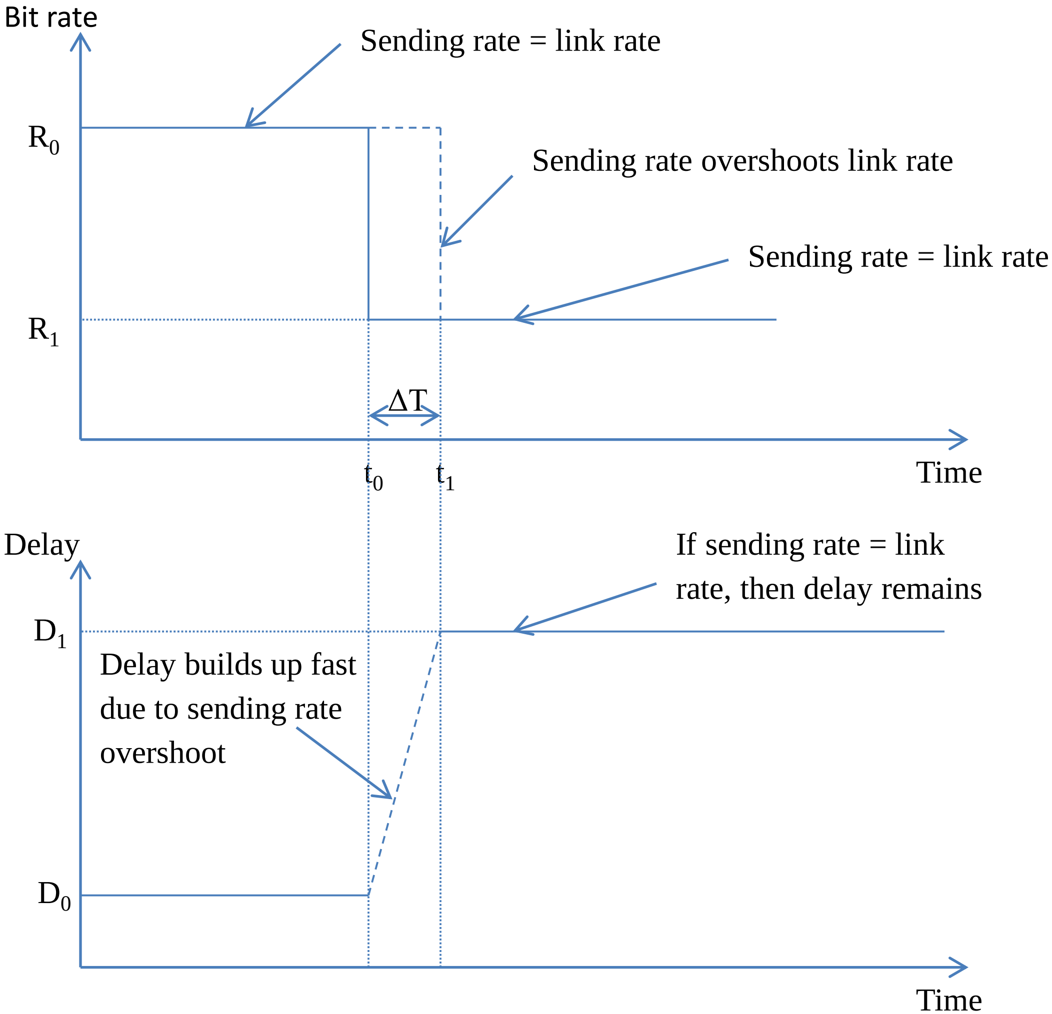
Introduction

- 3G/4G and Wi-Fi links experience time-varying channel capacities
  - Significant channel rate drops may occur
- Reaction delay before the sender reduces encoding bitrate:
  - Delay from bottleneck queue to receiver
  - Receiver-side congestion detection delay
  - Feedback message generation (TMMBR, …)
  - Reverse path delay (congestion?)
  - Sender-side feedback message handling
  - Sender’s rate control delay (rate reduction implementation differences)
    - Potentially resolution and frame rate changes
- During reaction delay, the sender’s encoding rate is higher than the available rate and excess bits are buffered at the bottleneck link resulting in delay buildup and potentially packet losses
- Delay buildup in the bottleneck queue will continue until reduced rate flow reaches it

Reaction Delay Upper Bounds

- Reaction delay (ΔT): theoretical



Example:
max delay buildup (D_1-D_0) = 200ms

R_0 = 600kbps
R_1 = 300kbps

$$\Delta T < \frac{R_1(D_1 - D_0)}{R_0 - R_1}$$

ΔT < 200ms

R_0 = 800kbps
R_1 = 300kbps

ΔT < 120ms

R_0 = 1200kbps
R_1 = 300kbps

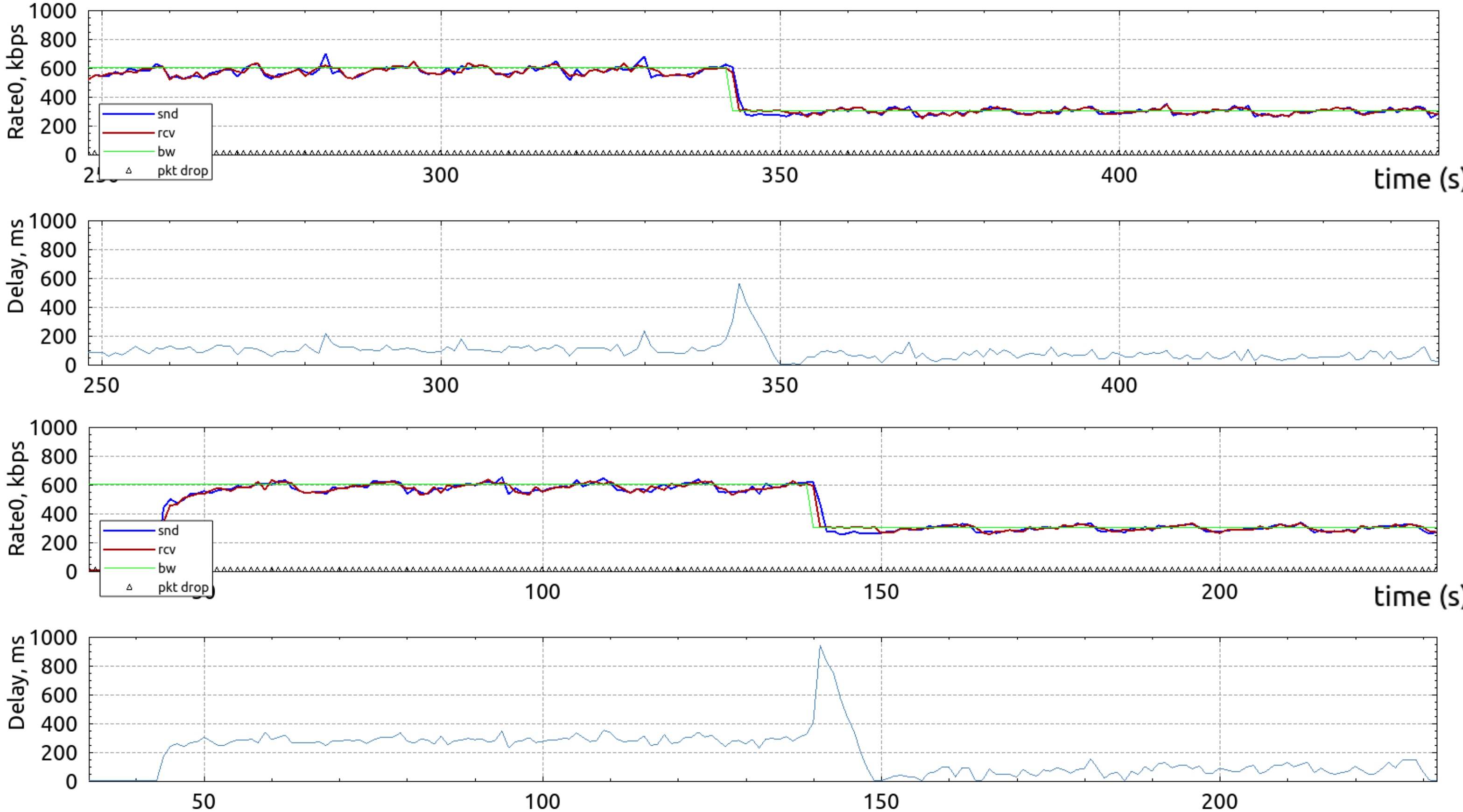
ΔT < 66ms

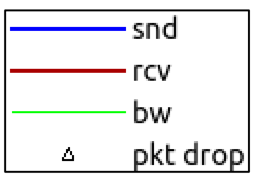
Upper bounds on ΔT are not always achievable

Delay Buildup Examples

- Examples for different RTTs
  - RTTs: 150/300ms; rate drop 600kbps to 300kbps (10kB TBF)
  - Encoders: HEVC/H.265, VP8 (WVGA30 live camera)
  - Google CC + modifications to support various encoders

HEVC
150ms

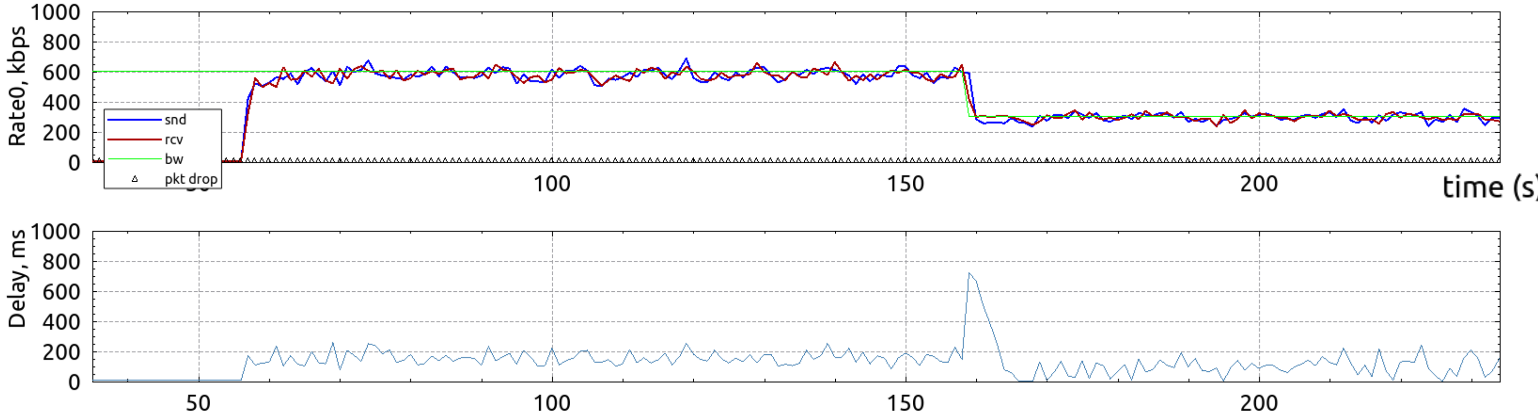


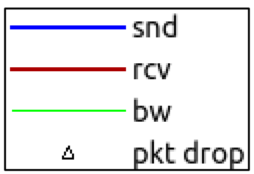


HEVC
300ms

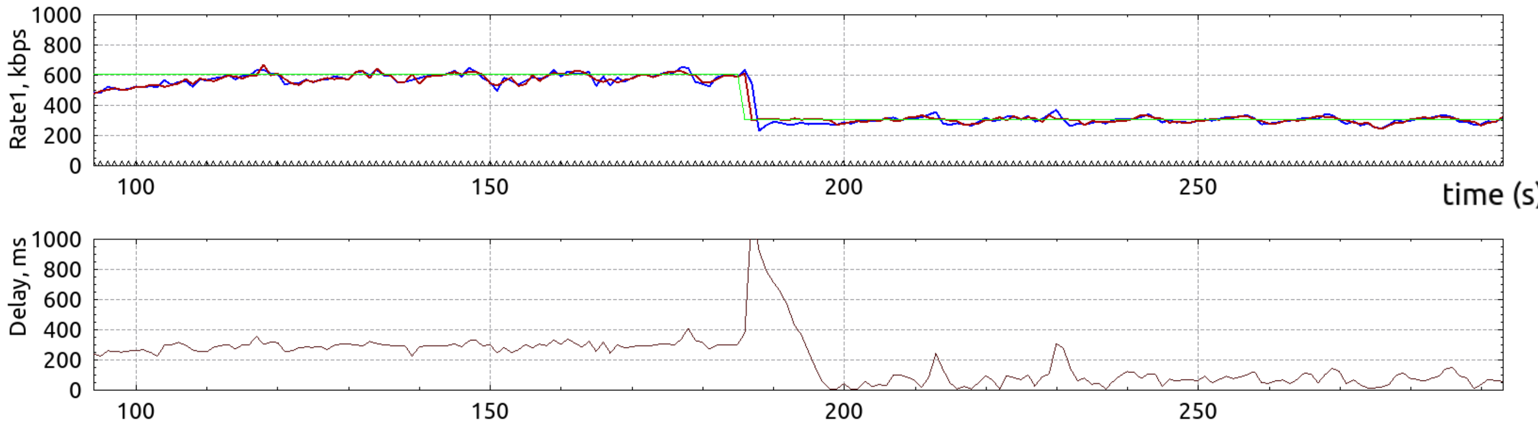
Delay Buildup Examples

VP8
150ms

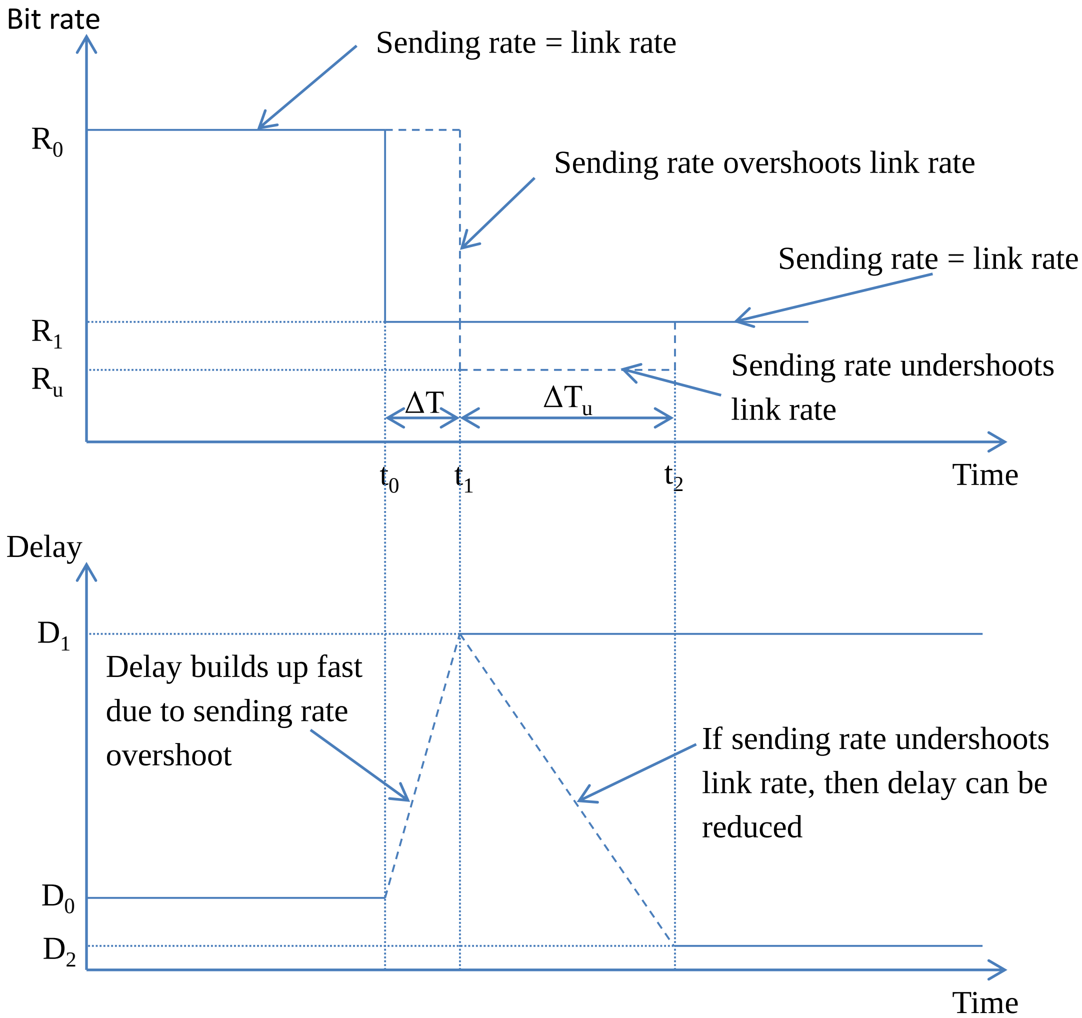




VP8
300ms



Delay Recovery Phase



- Goal is to reduce built-up delay due to rate down-switch
- Temporary delay recovery phase is started after the TMMBR is received at sender-side
- Sending rate undershoots max allowed rate by TMMBR
- Length of delay recovery is ΔT_u

Delay Recovery Phase

- Computing the delay recovery or rate undershoot duration ΔT_u
  - Let $R_U = (1-f_U) \times R_1$ with f_U determining the rate undershoot factor $(1-f_U)$ and $0<f_U<1$, which relates the undershoot rate to the link rate R_1
  - f_U may be dependent on the magnitude of the link rate drop $\Delta R = (R_0-R_1)$. For example, if ΔR is large, then f_U may be proportionally large or if ΔR is small, then f_U may be proportionally small
  - If we assume that the bits during ΔT are all buffered and are contributing to the delay, the period ΔT_u can be computed as follows:

$$\Delta T_u = \Delta T\ (R_0-R_1)\ /\ (f_U\ R_1)$$

  - A minimum bit rate requirement for the encoder may exist that applies to R_U and, therefore, also to f_U:

$$R_U \geq R_{min}$$

$$f_U \leq 1-(R_{min}/R_1) \quad \text{with } R_1 > R_{min}$$

  - How to estimate ΔT is interesting problem

Delay Recovery Examples

- Examples for different RTTs
  - RTTs: 150/300ms; rate drop 600kbps to 300kbps (10kB TBF)
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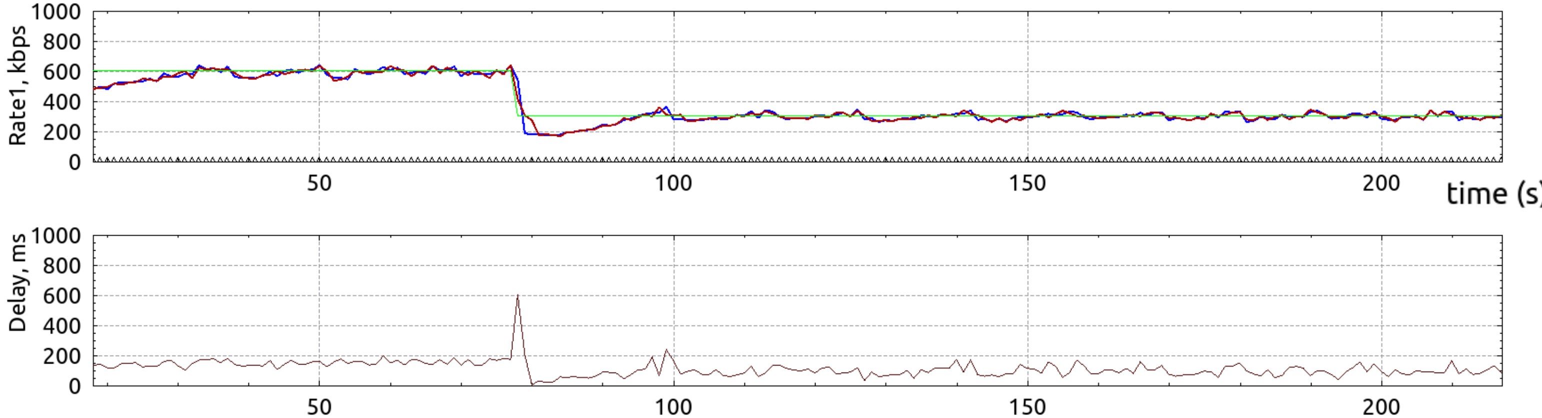
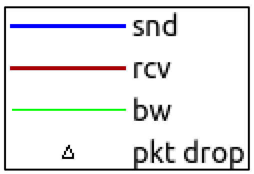
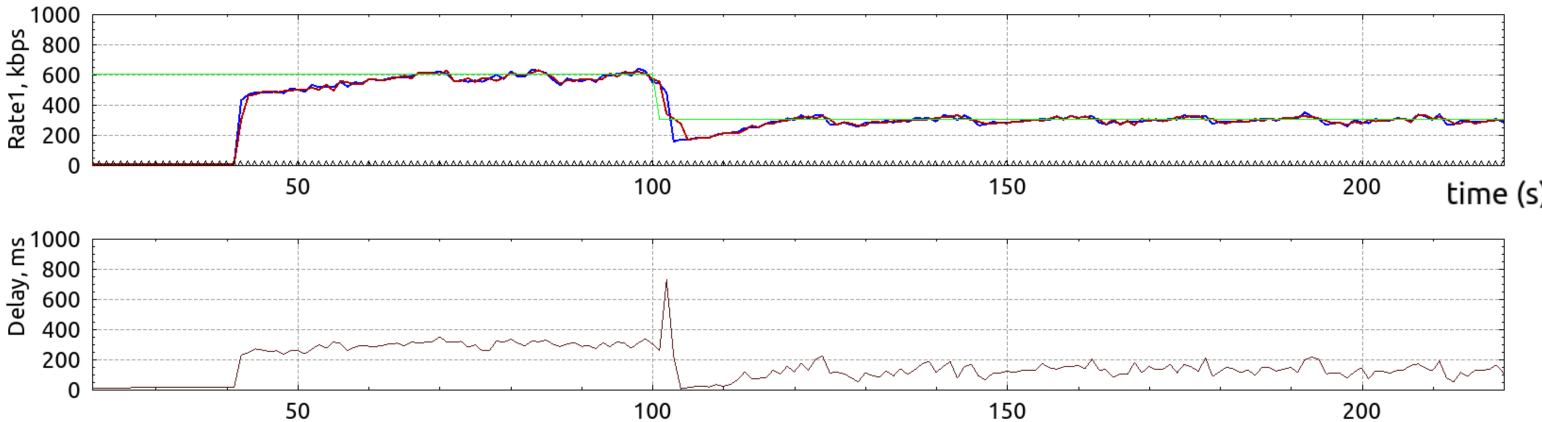
  - Delay recovery integrated with Google CC + modifications to support various encoders

HEVC 150ms



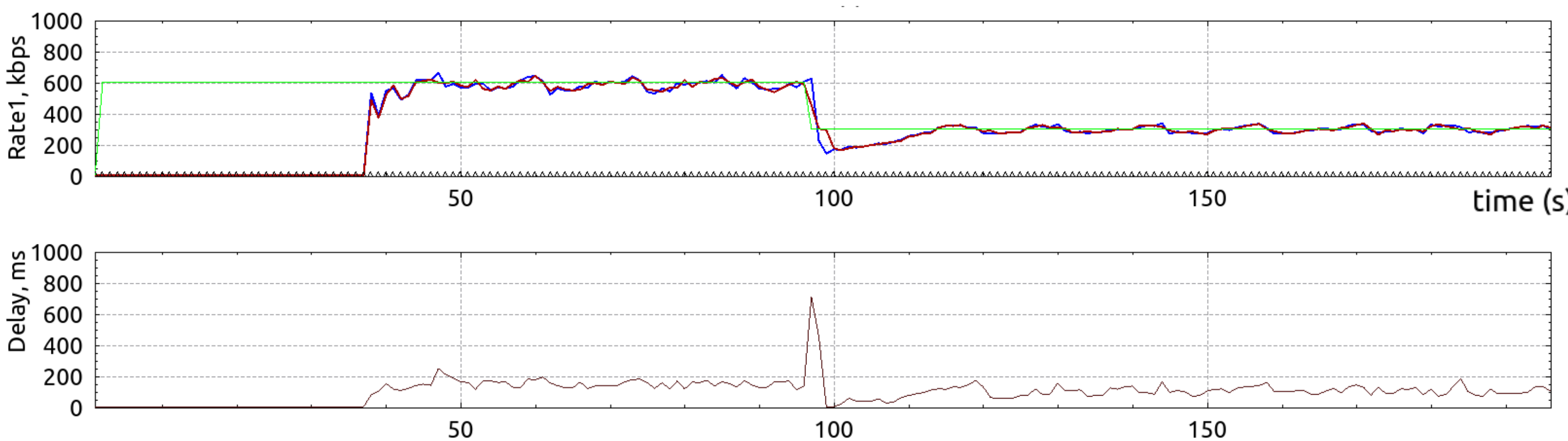


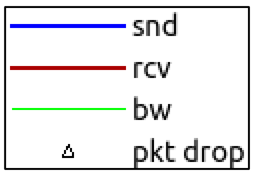
HEVC 300ms



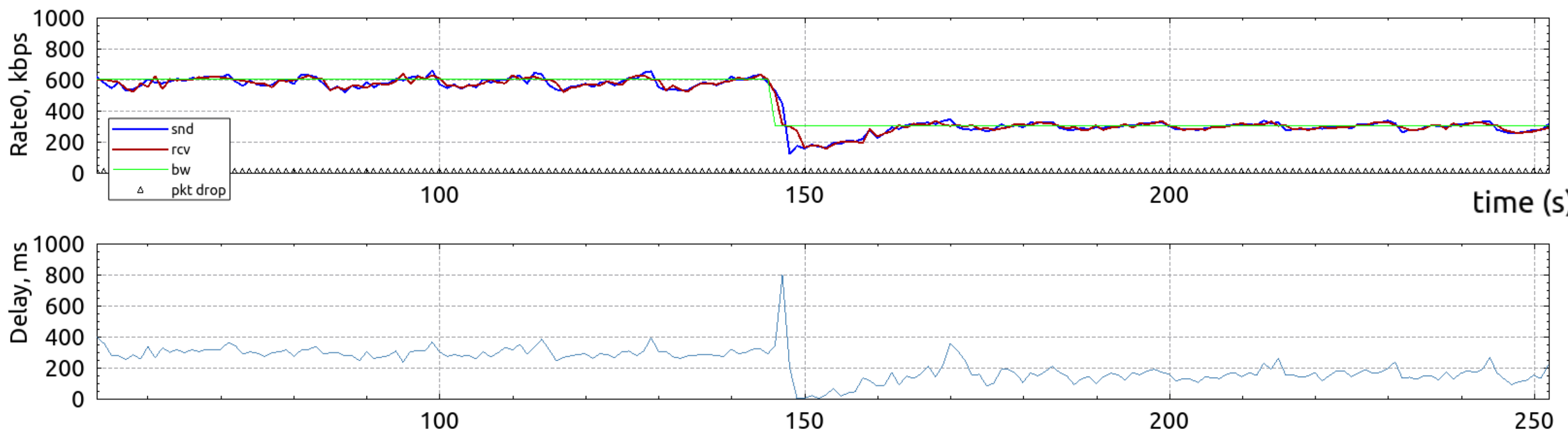
Delay Recovery Examples

VP8
150ms



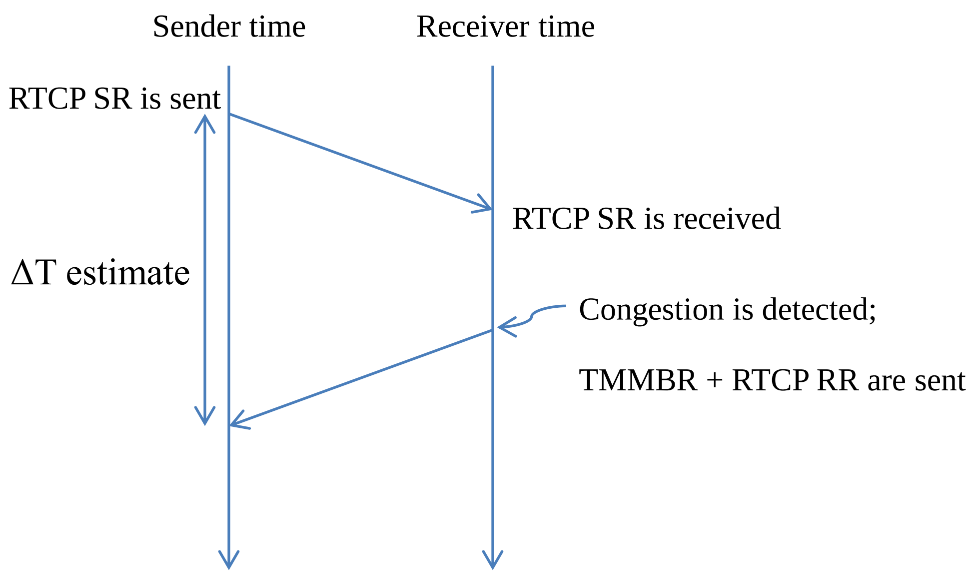


VP8
300ms



Delay Recovery: ΔT

- The receiver sends a minimal compound RTCP packet including the RR and TMMBR message immediately after congestion is detected
- With this information, the sender can make an estimate of ΔT as the time difference between the sending time of the RTCP SR (referenced in the RR by LSR) and the time that the RR+TMMBR is received, assuming that the congestion was detected at the receiver side after this particular SR was received



Conclusion

- Large channel rate drops can cause severe delay buildups due to the reaction delay before the sender can reduce the encoding rate
- In this case, a delay recovery phase is required to reduce the built-up delays quickly
- A method was presented to estimate the delay recovery or rate undershoot duration
- It is proposed to study and develop the delay recovery phase for RMCAT flows