SELF-CLOCKED RATE ADAPTATION FOR CONVERSATIONAL VIDEO IN LTE

CSWS'14

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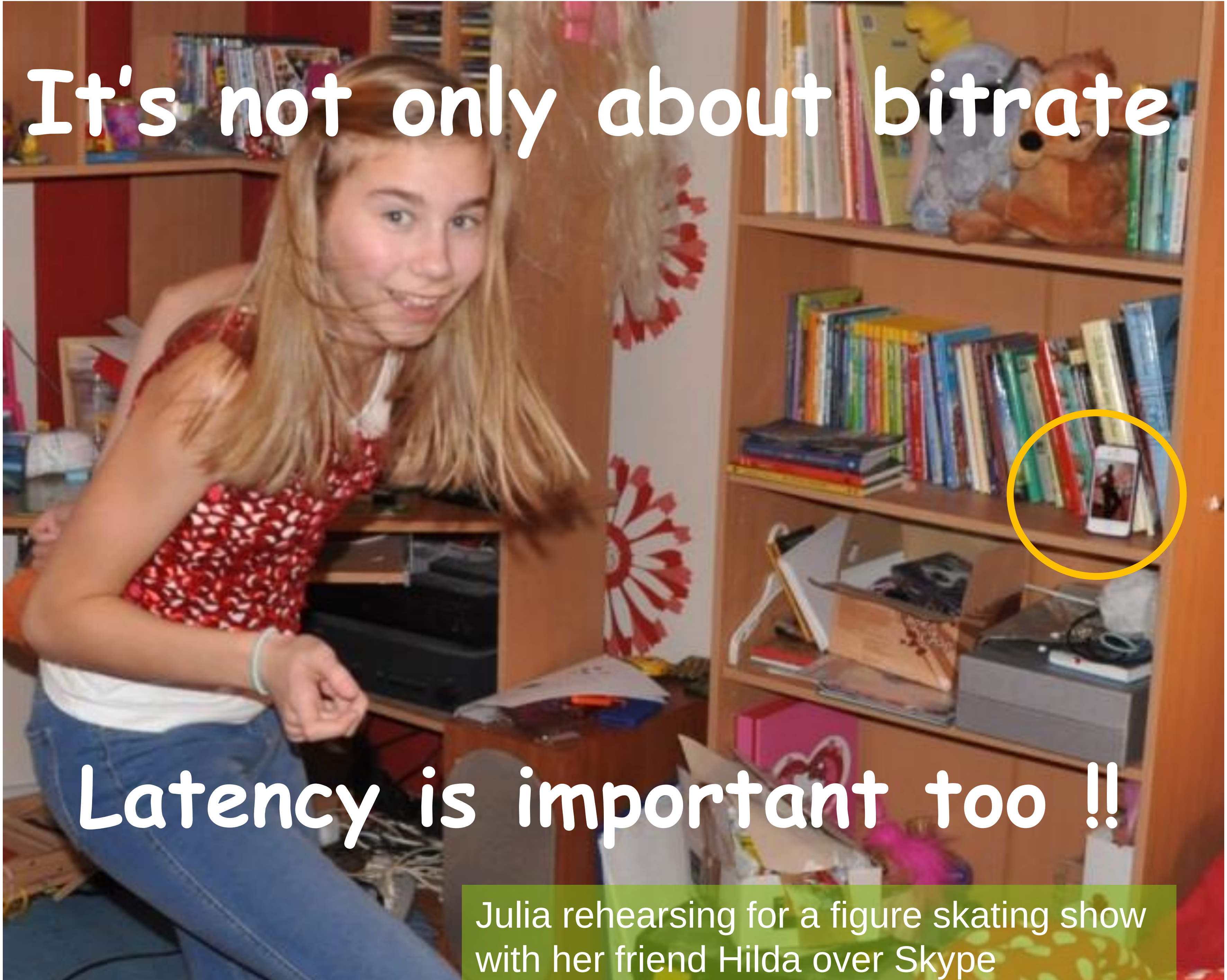


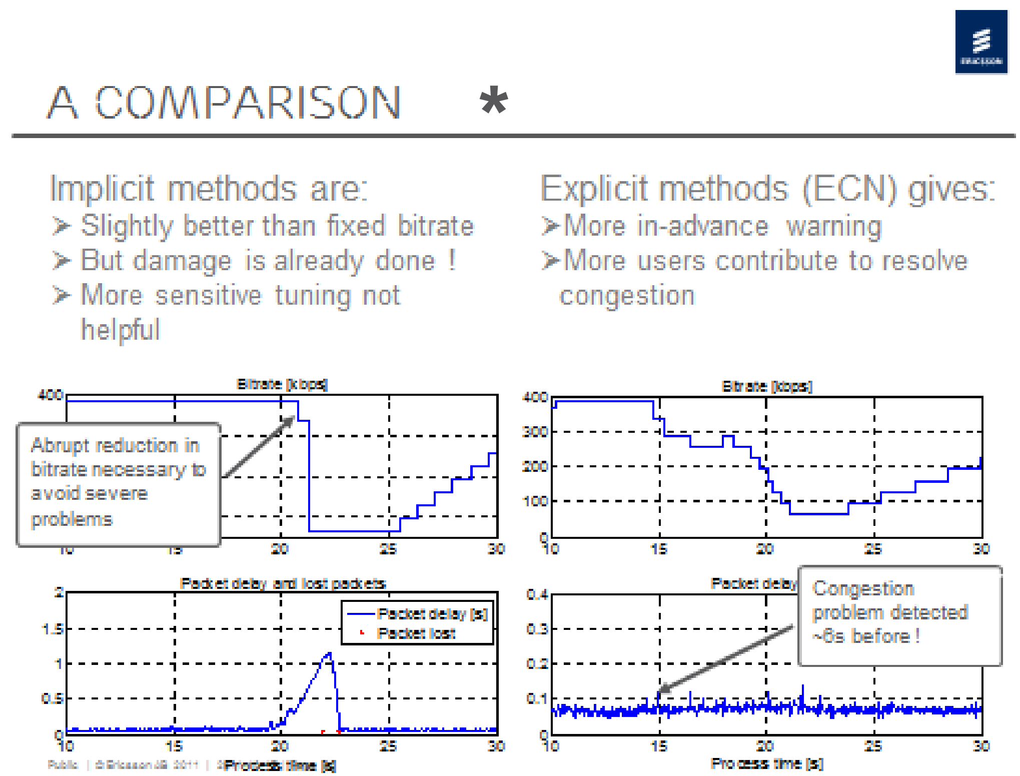
Julia rehearsing for a figure skating show with her friend Hilda over Skype

ENDPOINT CONGESTION CONTROL

- Two types
  - Rate based congestion control
    - GCC = Google CC (congestion control)
    - MTSI (3GPP TS26.114)
  - Self-clocked congestion control
    - TCP
    - TFWC (**T**CP **F**riendly **W**indow based **C**ongestion Control)
    - SCReAM (**S**elf-**c**locked **R**at**e** **A**daptation for **M**ultimedia)

ENDPOINT CONGESTION CONTROL, THE PROBLEM

- Rate based CC seems to be unable to combat congestion in LTE well
- Root cause, packet conservation principle is not followed.
- ECN is one solution to problem

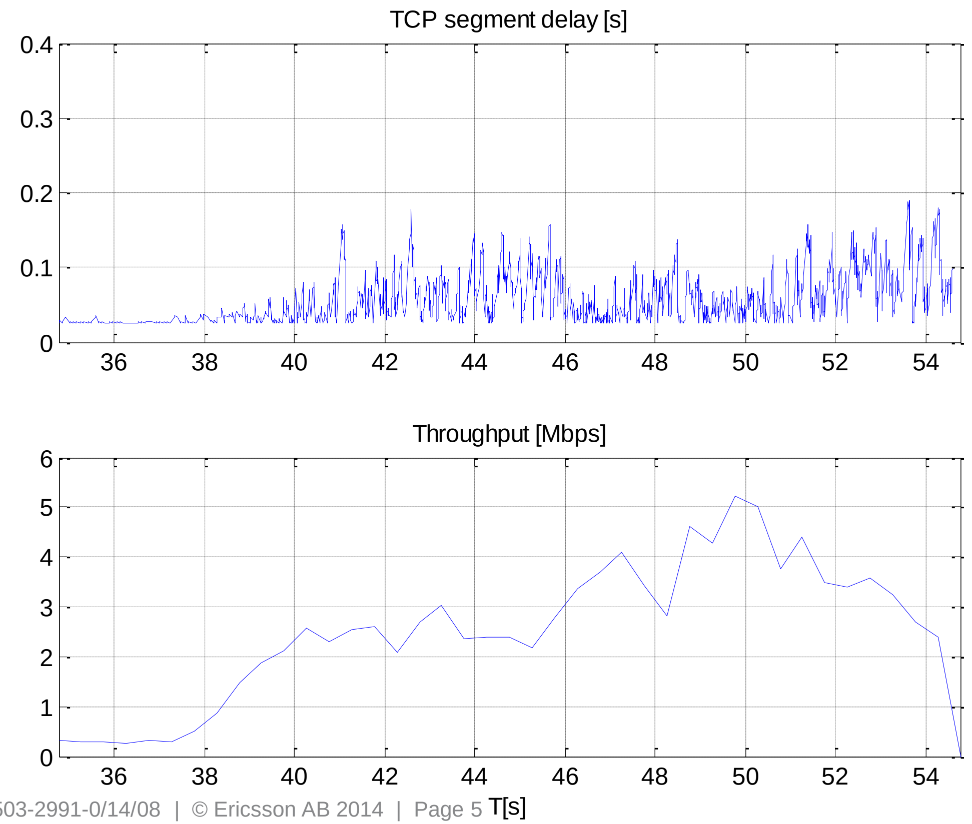


ECN :Explicit Congestion Notification

* http://www.uppersideconferences.com/volte2011/volte2011program.html
"Expanding VoLTE With Video Capabilities"

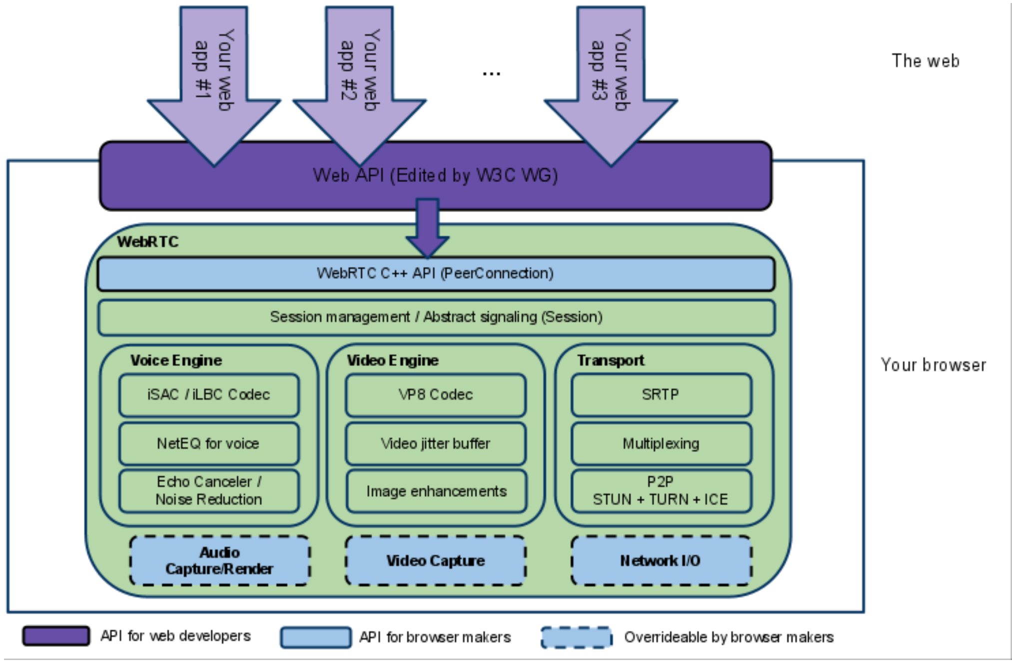
ENDPOINT CONGESTION CONTROL, THE SOLUTION ?

- File transfer with TCP LEDBAT
- Low latency despite quite a high bitrate !
- Packet conservation principle followed
- Can the same principles be used for conversational video ?



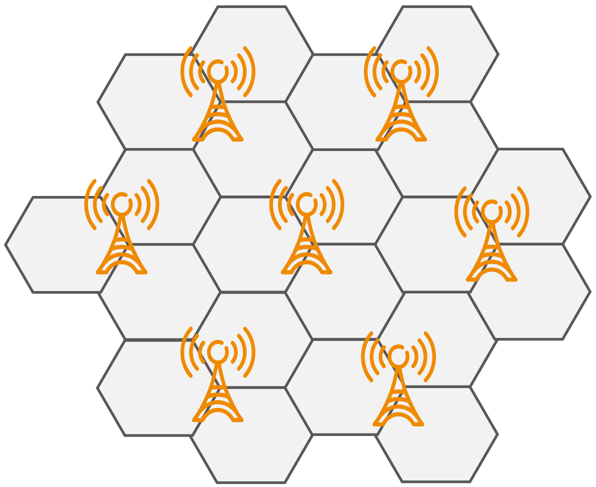
PROPERTIES OF CONVERSATIONAL MEDIA

- Example use case
  - WebRTC
- Audio + video
- Possibly also a data channel
- Varying number of streams



PROPERTIES OF LTE CHANNELS

- In general no guaranteed bitrate *
- LTE bearers are allocated to individual terminals
  - Low statistical multiplexing
- Throughput dictated by channel quality, number of users in cell and historical bitrate.
  - May change frequently, very little grace time to reduce bitrate



* QoS framework enables to prioritize e.g. for a given minimum bitrate

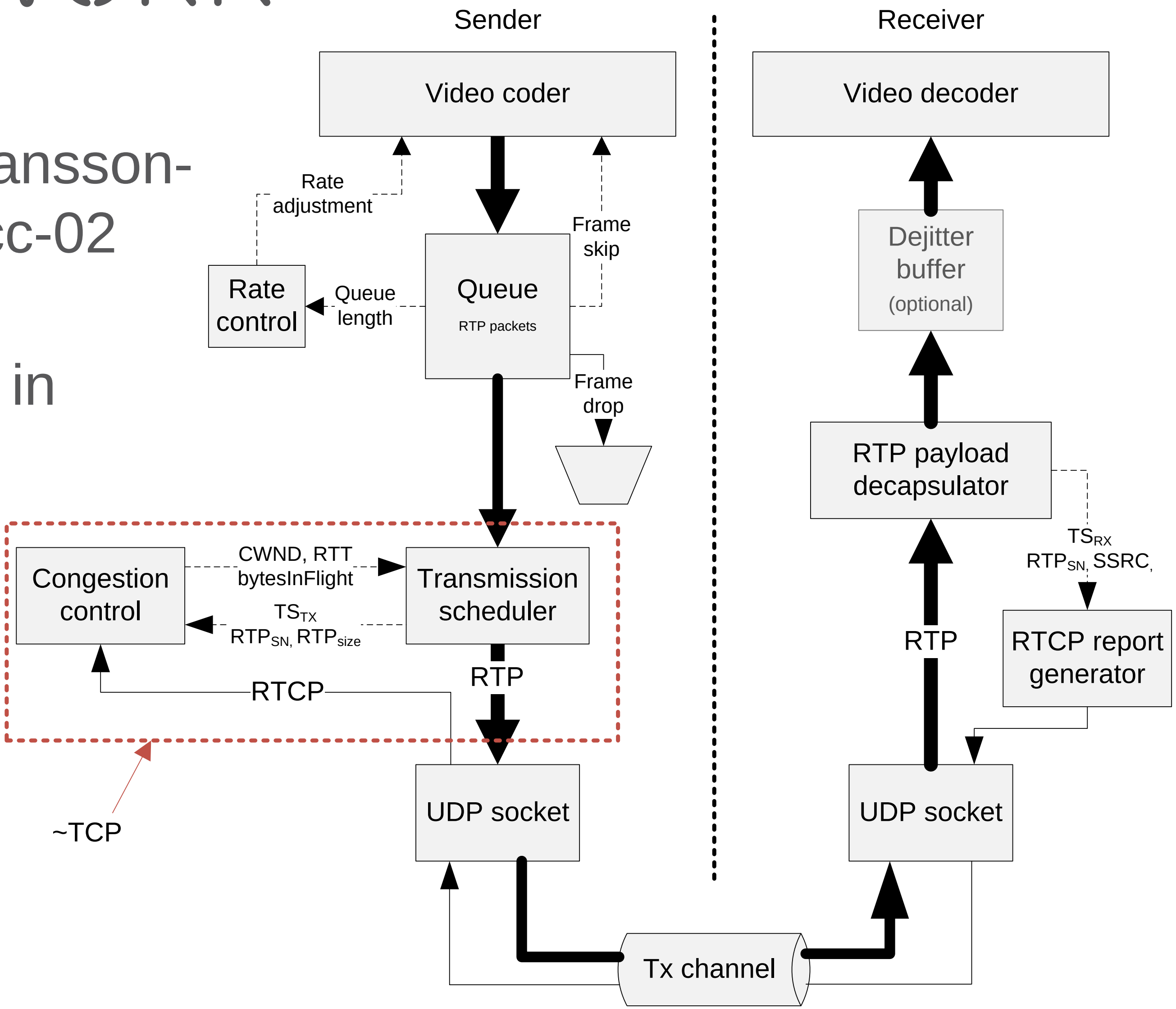
REQUIREMENTS ON A SOLUTION

1. Low latency and packet loss
2. Ability to coexist with other traffic over the same bearer
3. Stable bitrate

› #3 may be hard to fulfill given the two other requirements

THE ADAPTATION FRAMEWORK

- IETF : draft-johansson-rmcat-scream-cc-02
- Chromium implementation in progress



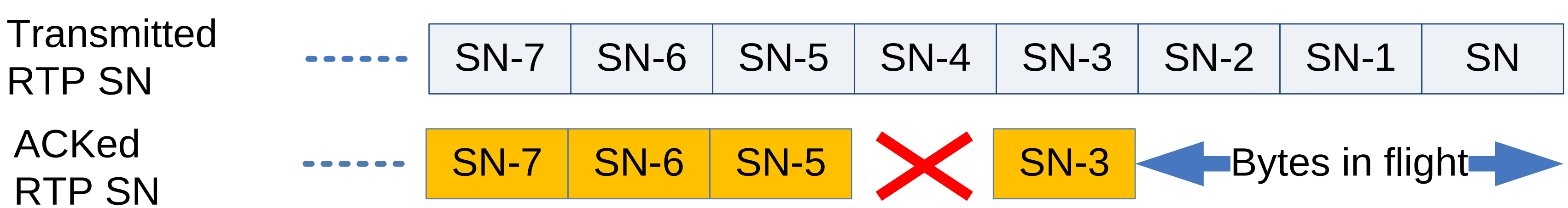
RTCP FEEDBACK

› RFC4585 Transport layer feedback message

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=2|P|    FMT   |       PT       |          length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  SSRC of packet sender                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  SSRC of media source                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Timestamp (32bits)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Last recv. sequence nr (16b)  | ECN echo        |Q|R|R|R|R|R|R|R|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    ACK vector (32b)                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

BUZZ WORDS

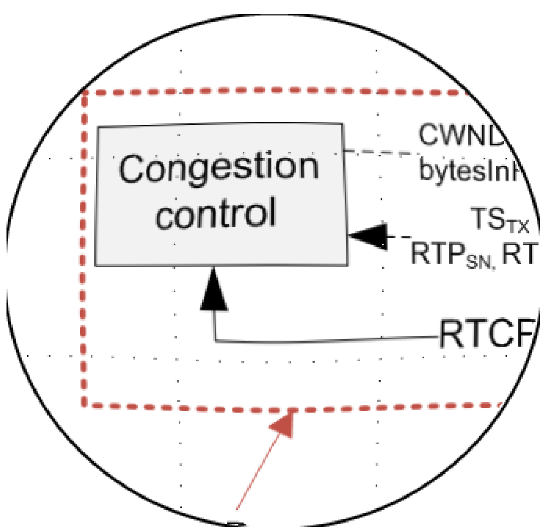
- CWND : Congestion window, determines max number of bytes in flight, size depends on estimated network queuing delay and packet loss or ECN
- Bytes in flight: The total size of the transmitted but not yet acknowledged RTP packets.

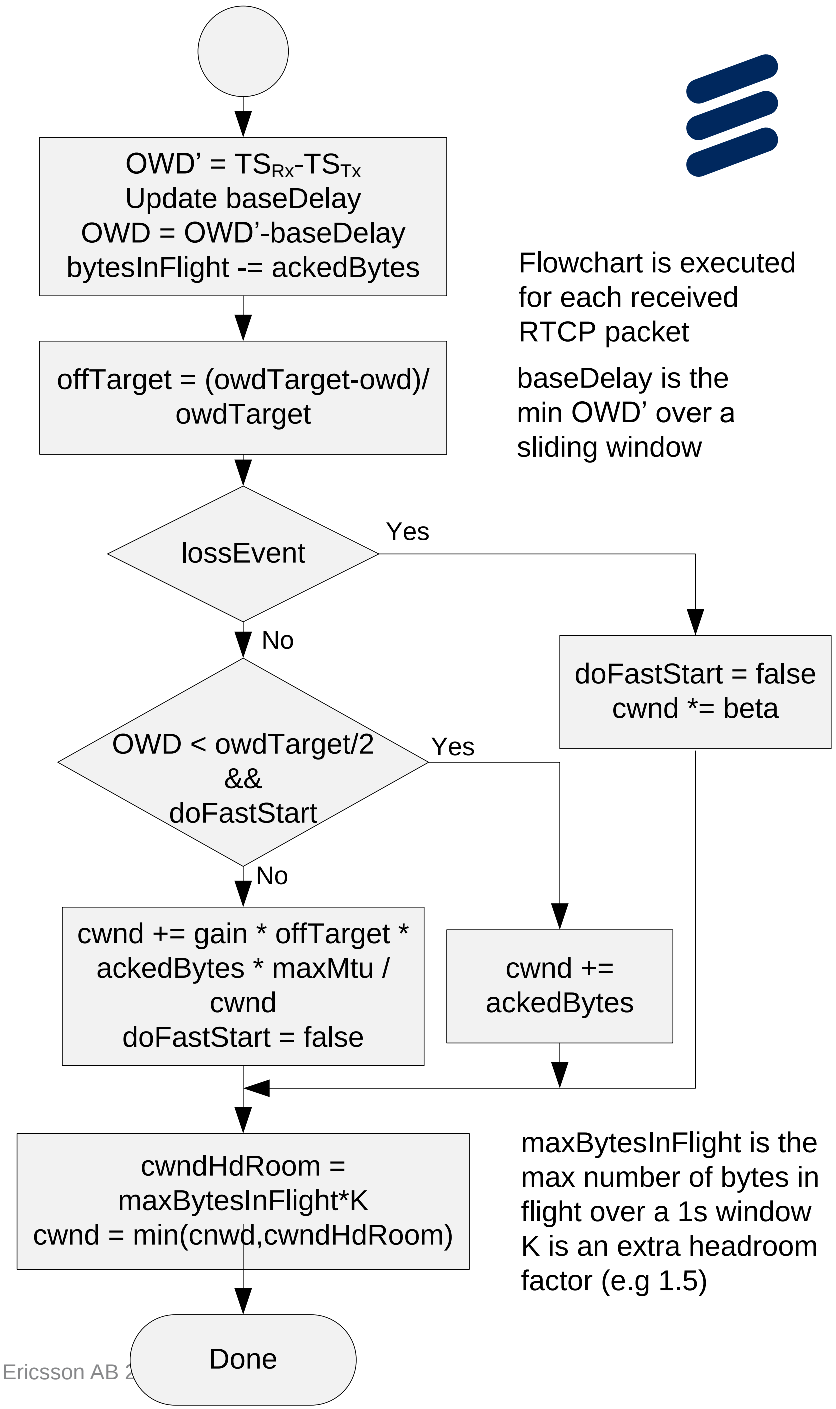


- OWD : One way (extra) delay. An estimate of how much the queues in the network increase

CONGESTION CONTROL

- Inspired by TCP and LEDBAT
- Additional features
  - Adaptive delay target
  - Random CWND reduction





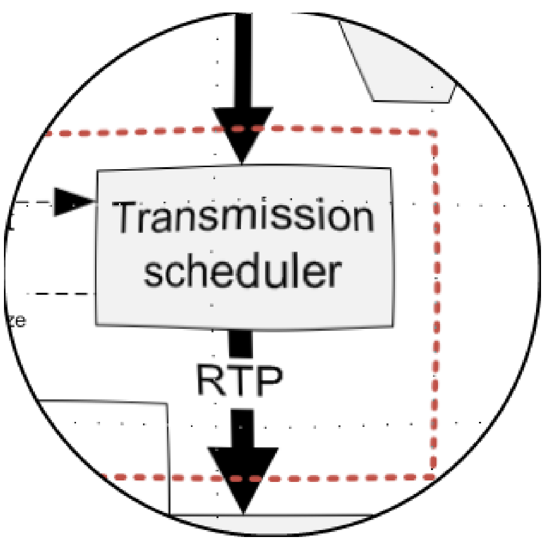
Flowchart is executed for each received RTCP packet

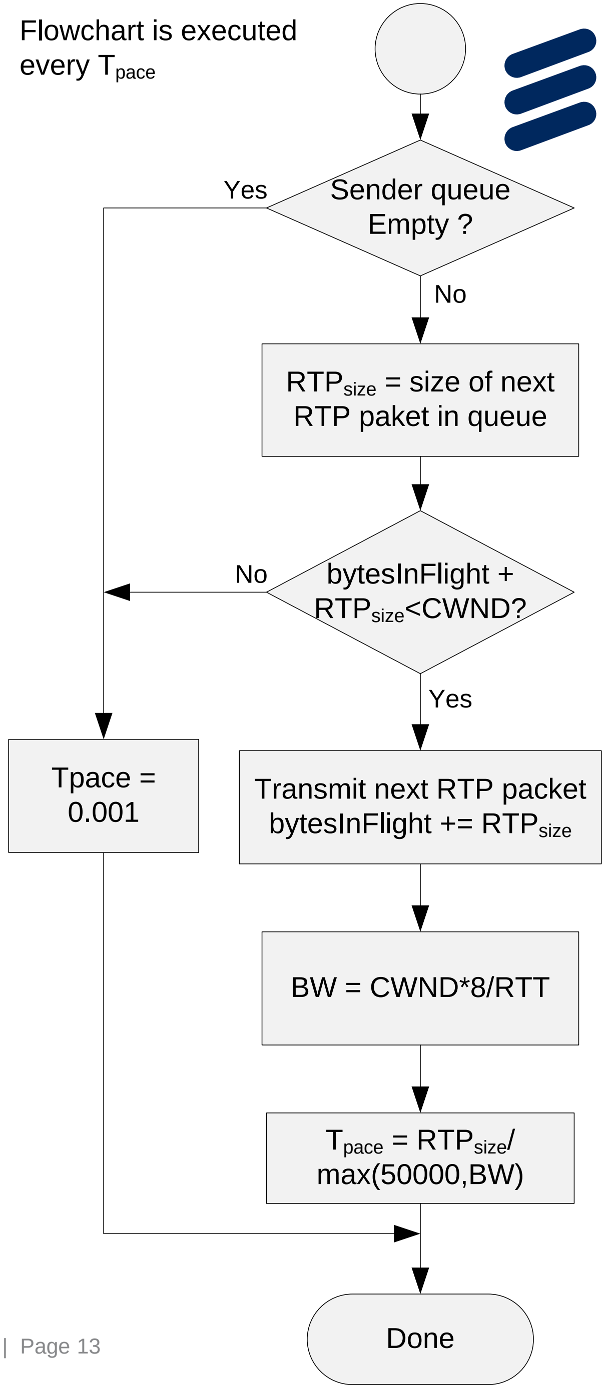
baseDelay is the min OWD' over a sliding window

maxBytesInFlight is the max number of bytes in flight over a 1s window
K is an extra headroom factor (e.g 1.5)

TRANSMISSION SCHEDULING

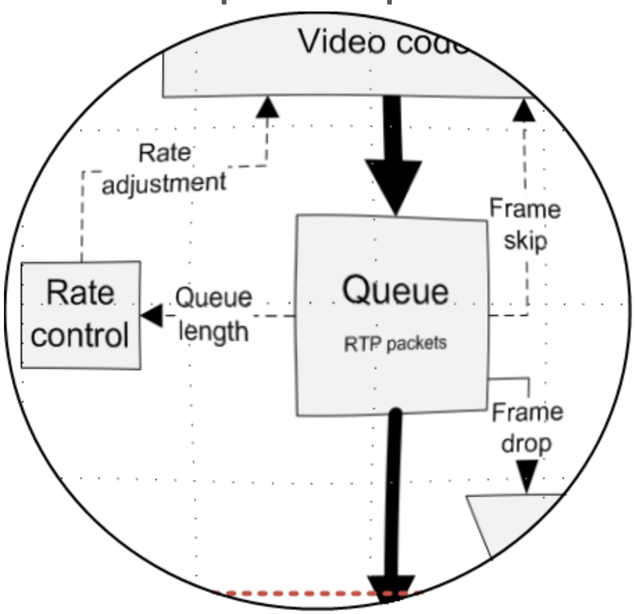
› Additional feature
  - Allow transmission even though bytes in flight > CWND in certain cases.

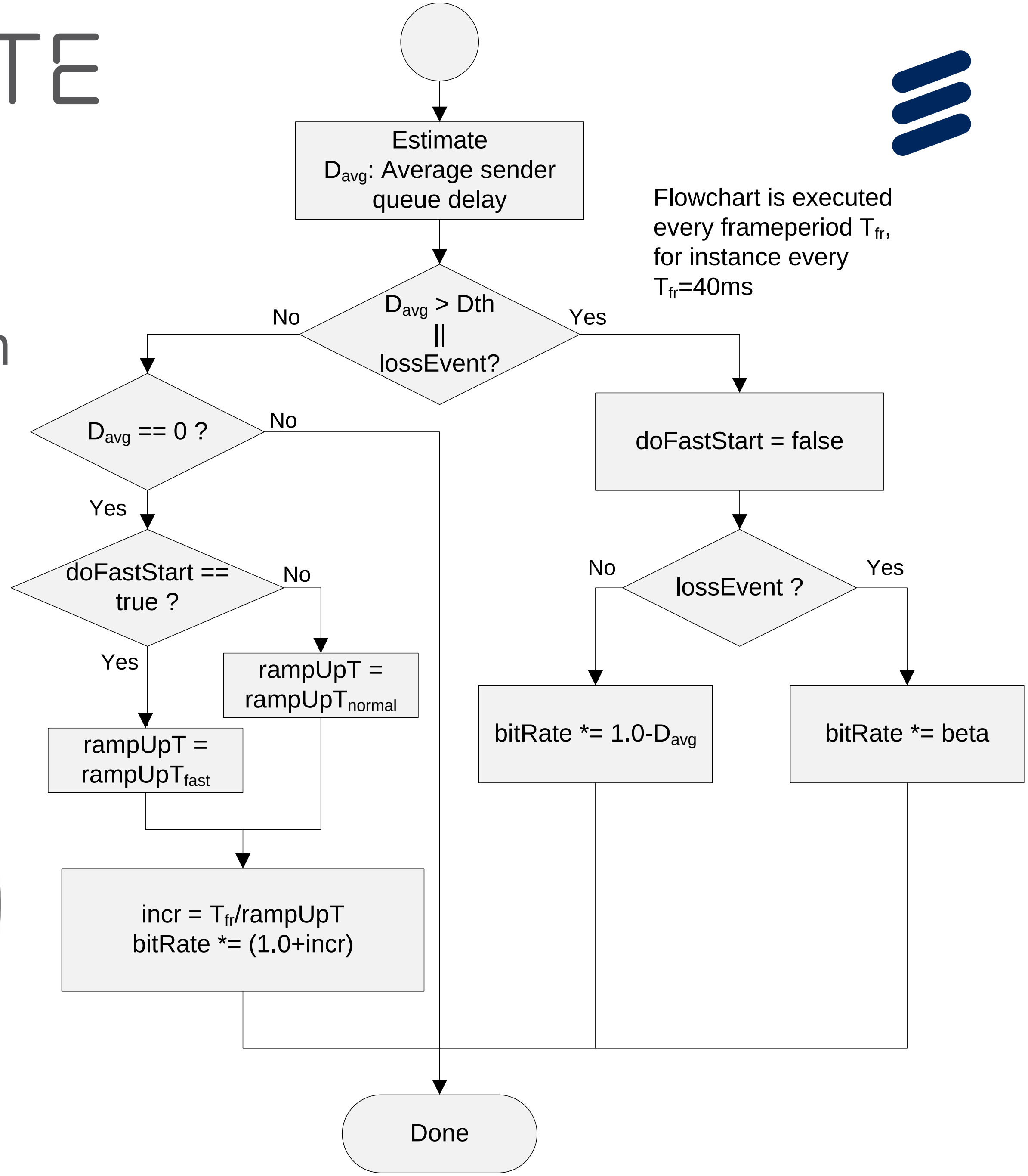




MEDIA RATE CONTROL

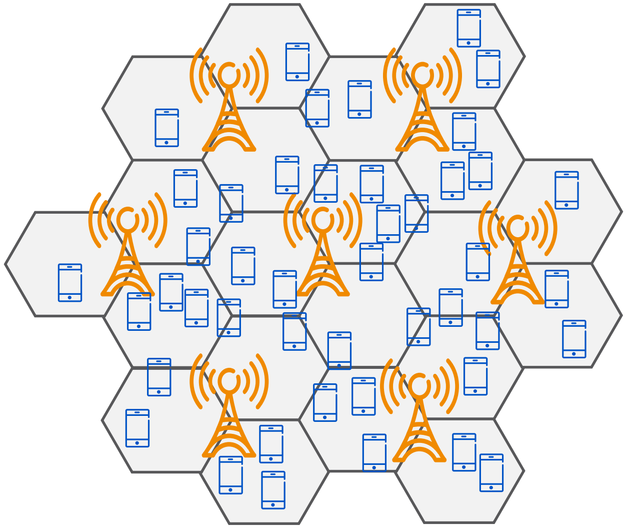
› Additional actions, in case sender queue grows too large
  - Skip frames
  - Drop RTP packets

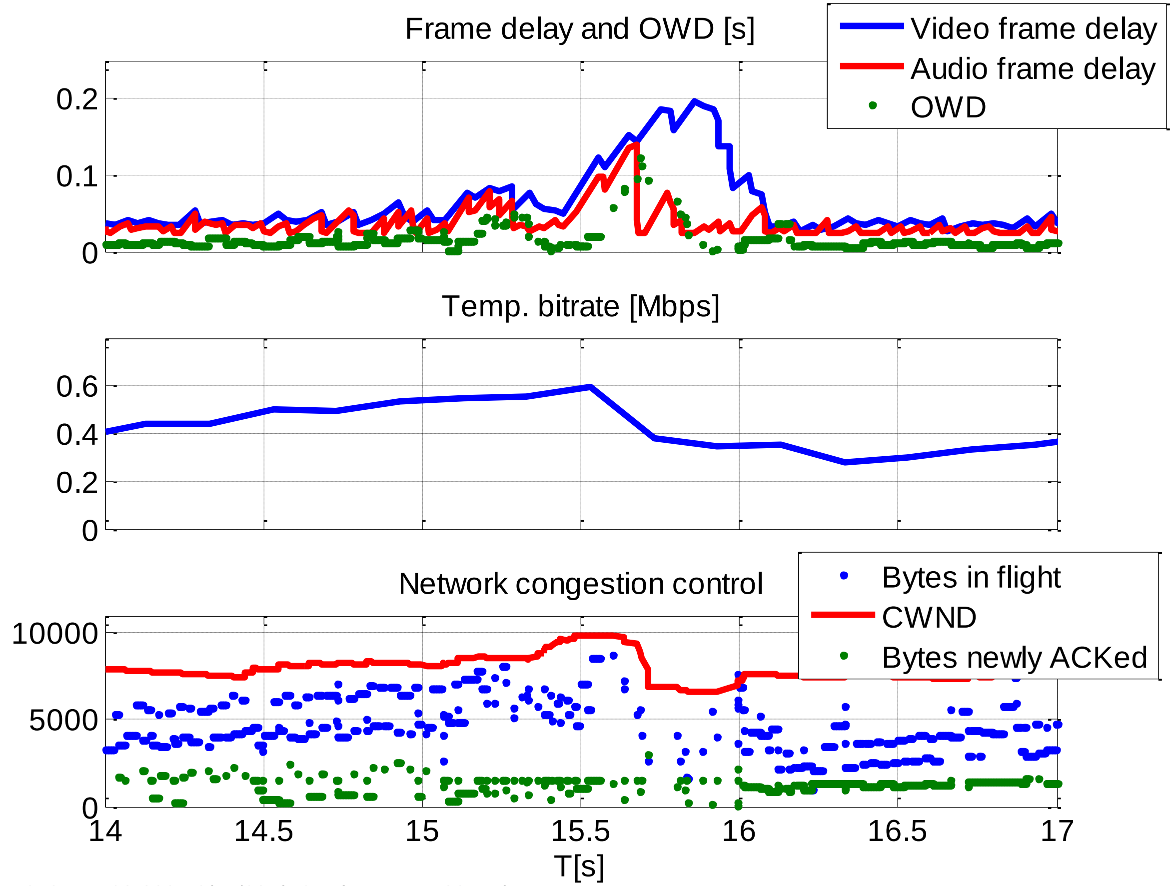




EXAMPLE 1 LTE CHANNEL

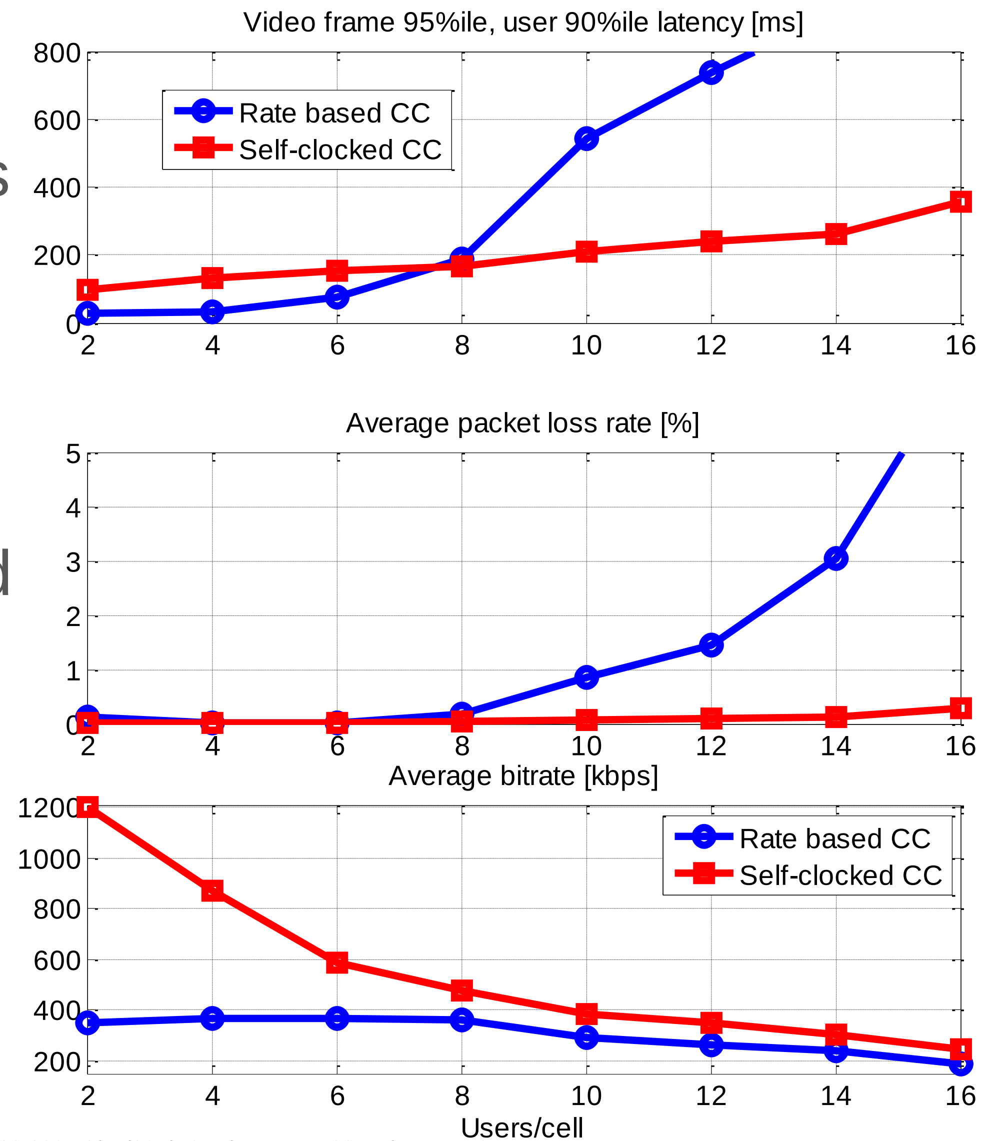
› Note the more sparse ACKs during the congestion event ~15.5 – 16.0s





COMPARISON SELF-CLOCKED VS RATE BASED CC

- Rate based CC increases bitrate very slowly → low average bitrate
- Self-clocked CC increases bitrate quickly → High bitrate at low load
- Still Self-clocked CC is more stable at higher load levels



DISCUSSION

- Self-clocked rate adaptation performs considerably better than rate based congestion control algorithms
- Possible remaining issues to solve
  - Over-reaction at handover
  - Over-reaction to congestion events
  - Negative impact from other cross traffic
  - Possibly frequent and large media bitrate changes
- Possible solution to the above listed issues
  - ECN
  - Network assisted rate adaptation

CONCLUSION

- Possible to implement well functioning conversational video over LTE
- Self-clocking is the key !
- Leverages on novel TCP features
- Solution realized with RTCP feedback
  - Solution can be complemented with more network centric support for enhanced performance

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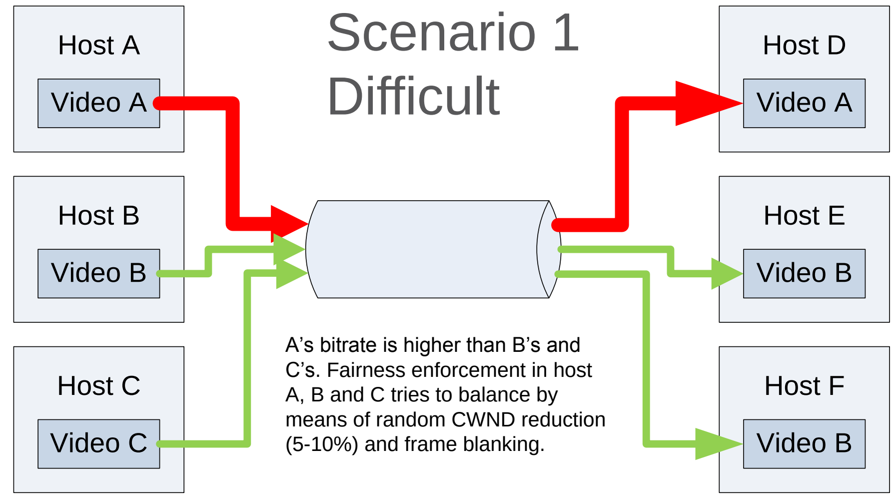
FAIRNESS ENFORCEMENT

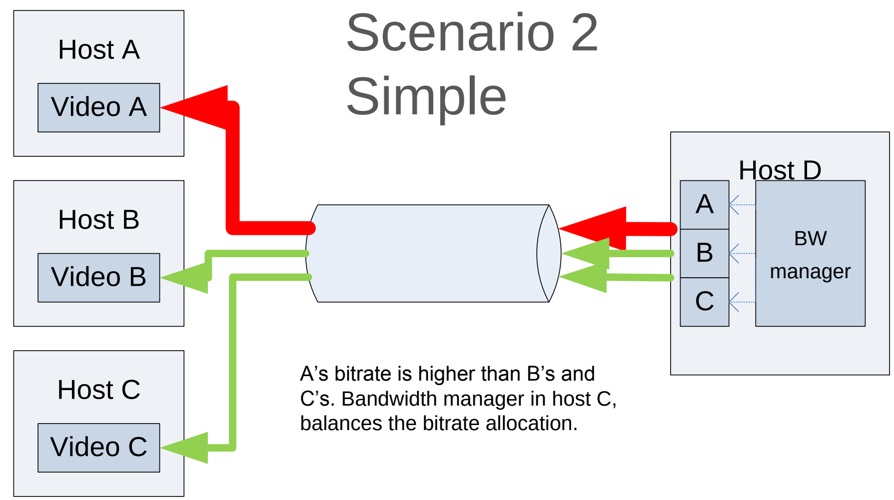
› Three scenarios

Scenario 1 Difficult



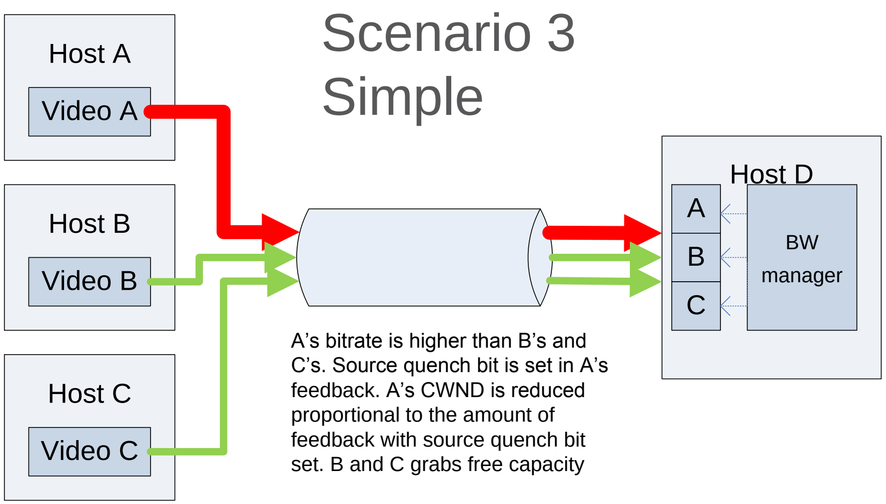
A’s bitrate is higher than B’s and C’s. Fairness enforcement in host A, B and C tries to balance by means of random CWND reduction (5-10%) and frame blanking.

Scenario 2 Simple



A’s bitrate is higher than B’s and C’s. Bandwidth manager in host C, balances the bitrate allocation.

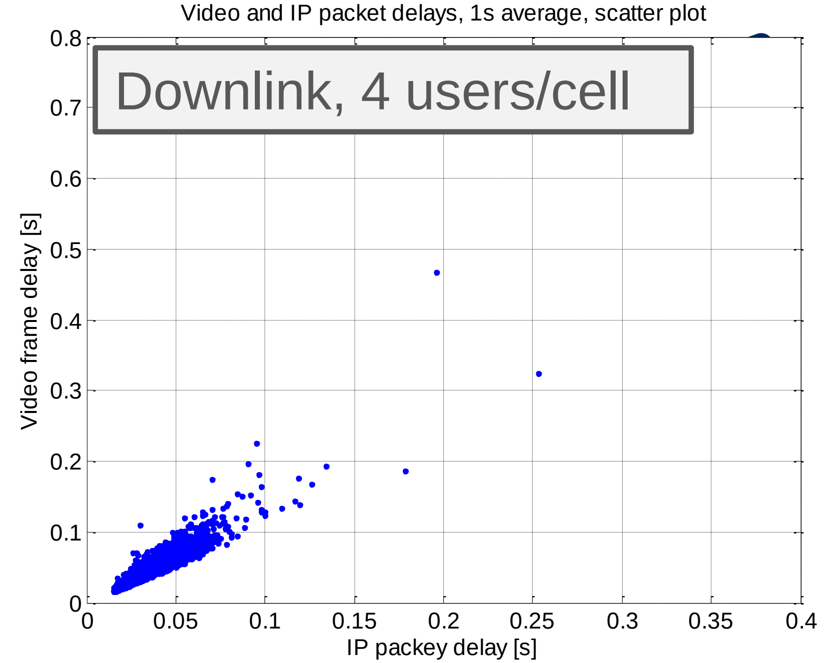
Scenario 3 Simple

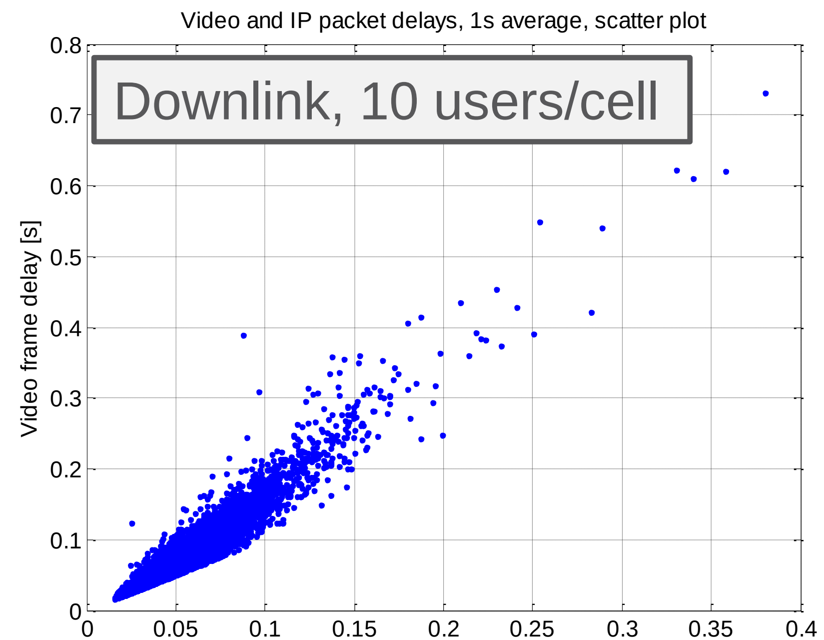


A’s bitrate is higher than B’s and C’s. Source quench bit is set in A’s feedback. A’s CWND is reduced proportional to the amount of feedback with source quench bit set. B and C grabs free capacity

ADDITIONAL DELAY IN SENDER QUEUE

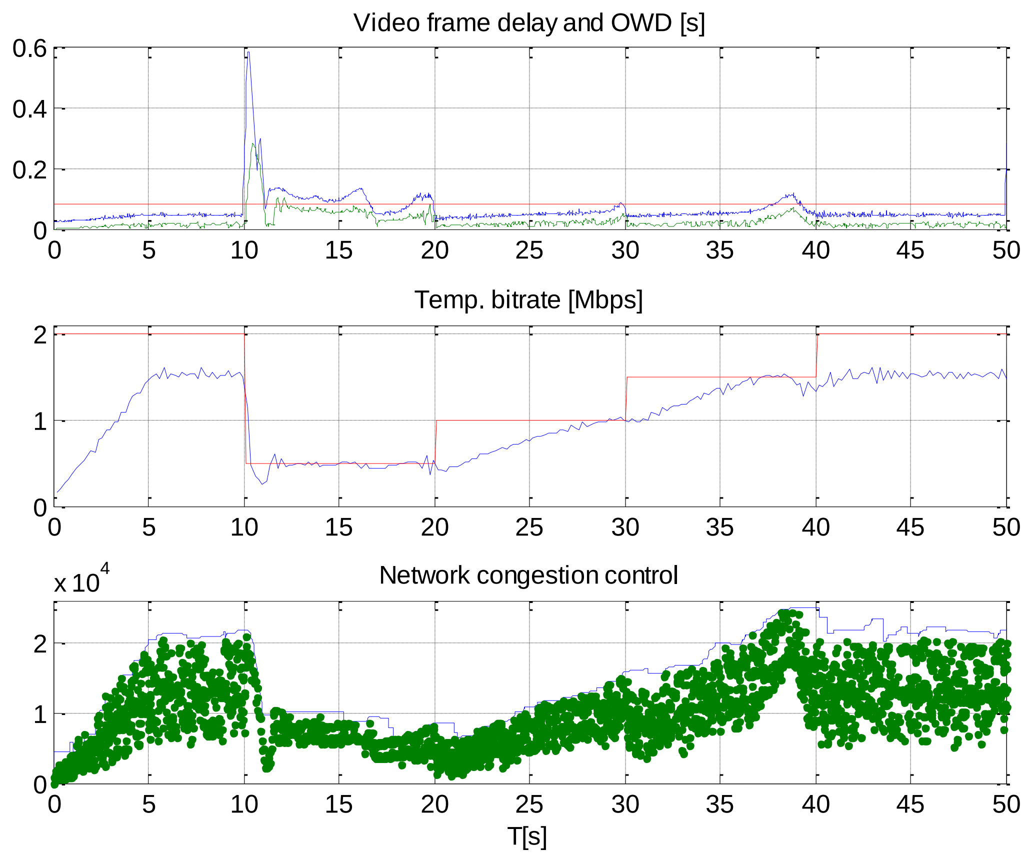
- Scatter plots of IP packet delays vs video frame delay indicate additional queuing in sender queue is strongly correlated to network queuing.
- Conclusion: Without a sender queue, the delay would likely occur in the network instead





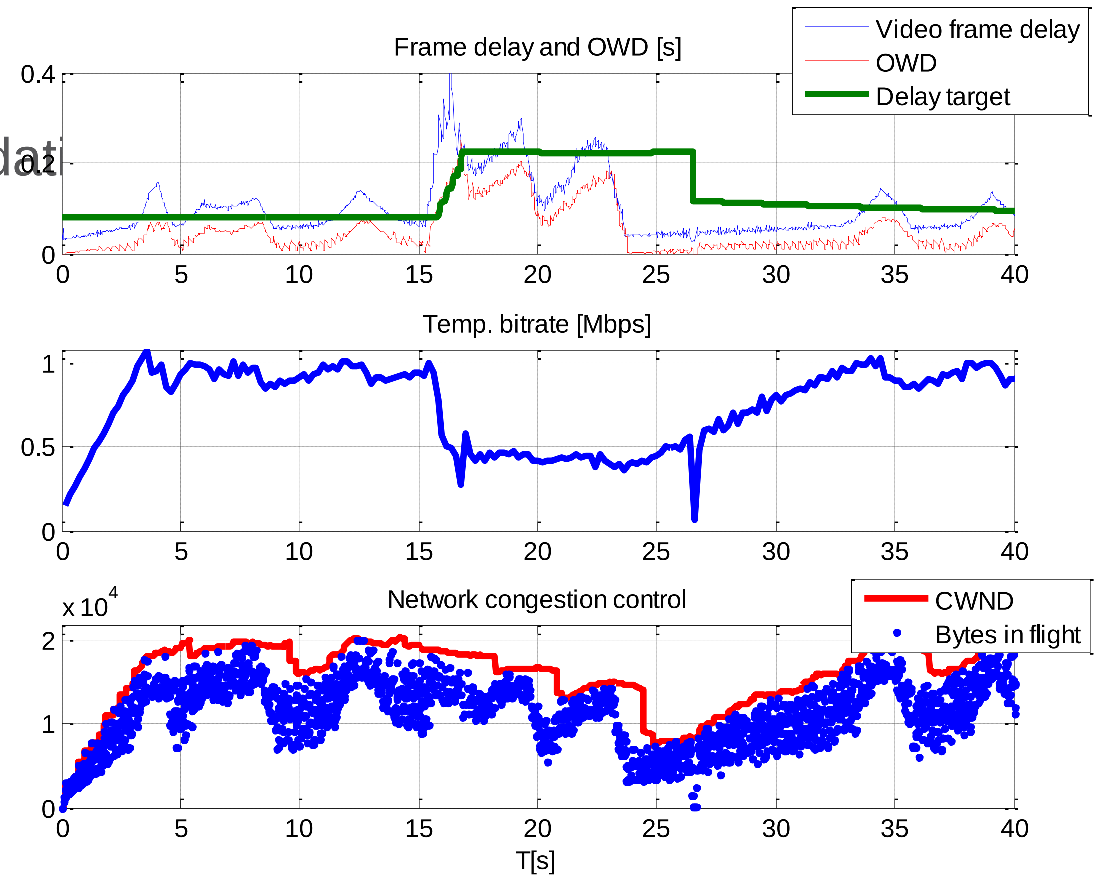
EXAMPLE 2
BOTTLENECK WITH CHANGING BW

› SCReAM reacts quickly to reduced throughput.



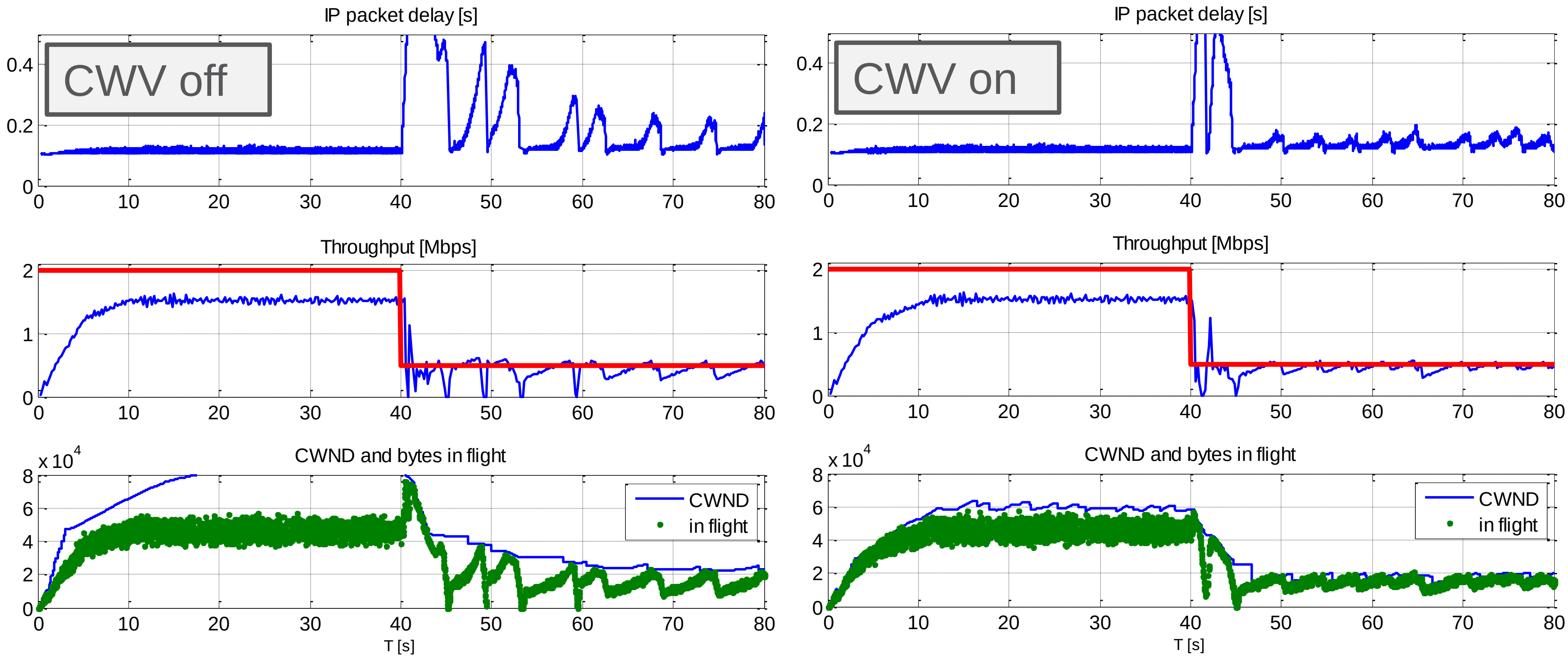
EXAMPLE 3
COMPETING FTP

› Three features :
 – Fast start
 – Adaptive delay target
 – Congestion window validati



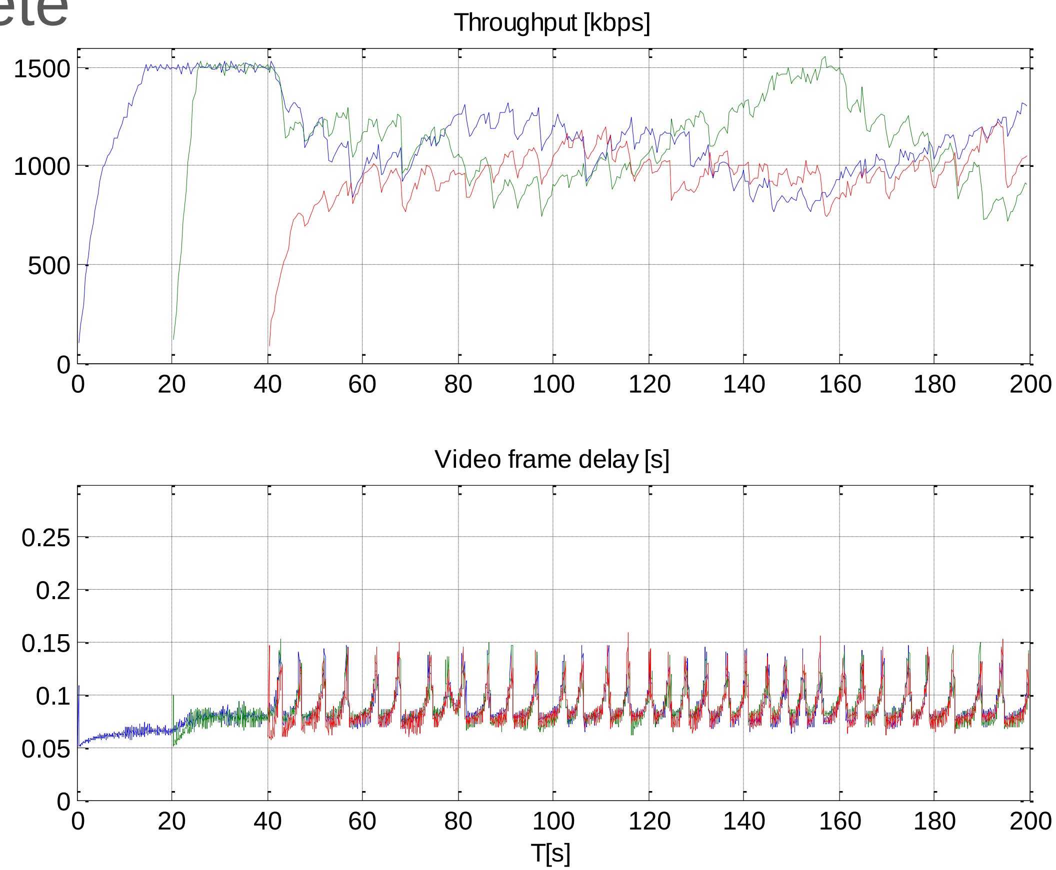
EXAMPLE 4
CONGESTION WINDOW VALIDATION

- Congestion window validation is crucial for the stability of the algorithm



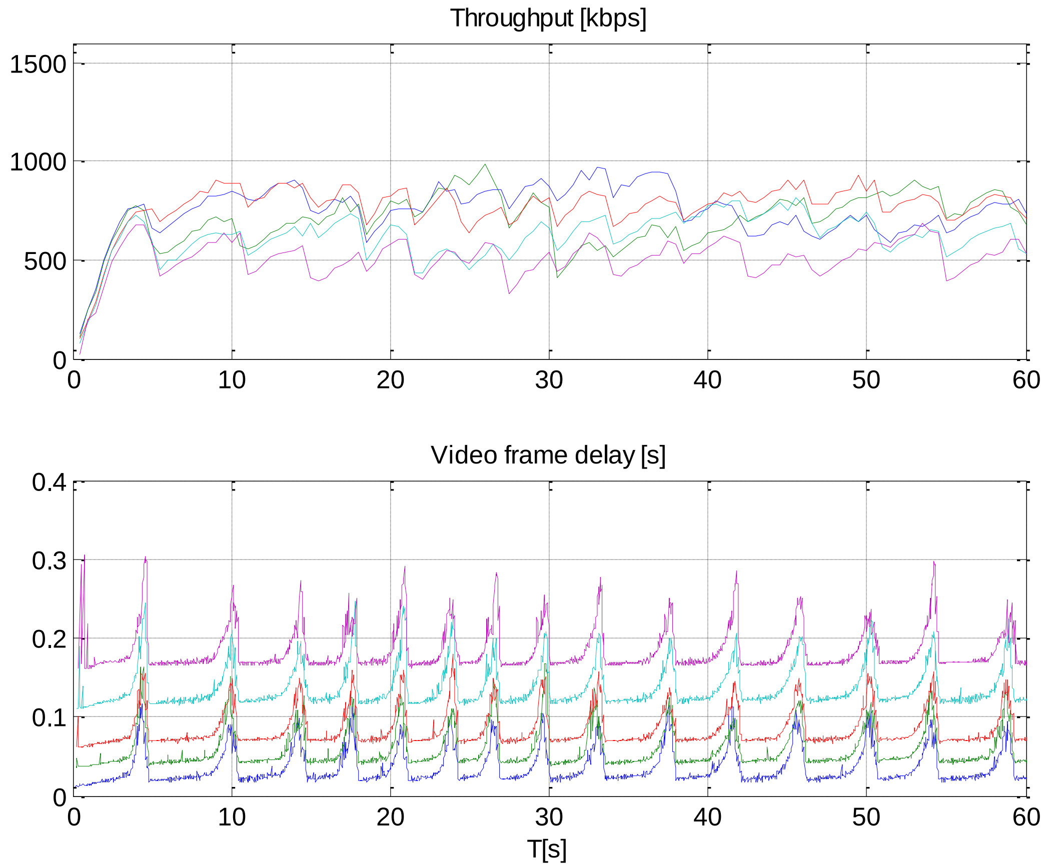
COMPETING RMCAT FLOWS

- RTT = 100ms
- 3 RMCAT flows compete



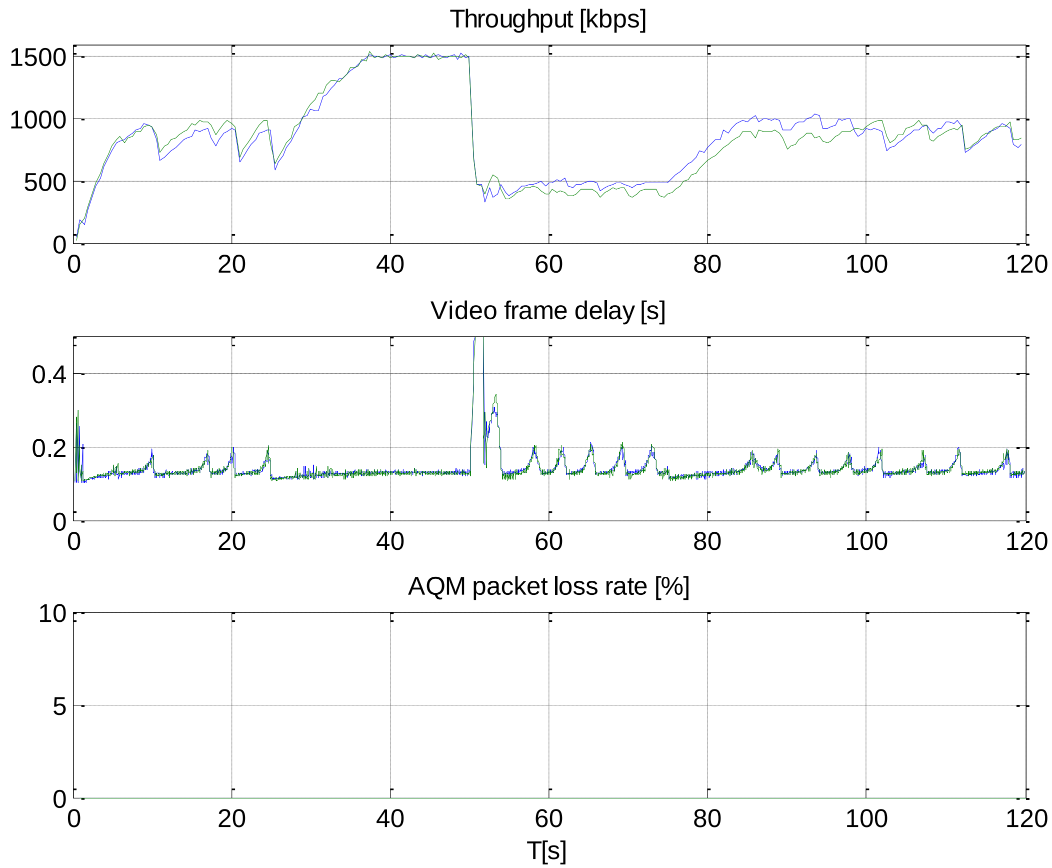
RTT FAIRNESS

› 5 flows with different RTT



VARIABLE BW

- Two RMCAT flows compete, changing bandwidth
- RTT 200ms



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