BBR
WITH
L4S SUPPORT
A FEW EXPERIMENTS AND FINDINGS

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INTRO

- BBR = Bottleneck Bandwidth and RTT (BBR) congestion control
  - Developed by Google
  - Estimated bottleneck bandwidth and min RTT, based on heuristics derived from normal TCP ACKs.

- Scope of this work :
  - Modify BBR with L4S support, (BBR evo)
  - No claims that this is the final, there is room for improvement
  - …But the changes so far are very minimalistic

- Note… these are simulations!

BBR evo MODIFICATIONS

1. L4S support added (ECN echo code from tcp_dctcp.c)
2. Function bbr_update_bw(…)
   Bandwidth estimates takes amount of CE marked packets into account
   - **bw = (rs->delivered) / rs->interval;**
     changed to
     bw = (rs->delivered-rs->delivered_ce/K) / rs->interval;
     where delivered_ce are the amount of delivered <u>and</u> CE marked packets in the given interval.
     K = 4 seems to be OK
   - Additional state variable(s) delivered_ce need where ‘delivered’ is specified

BBR evo MODIFICATIONS

3. Gain cycle changed to 3 RTTs (from 8 RTTs)
   – Reduced gain variation [9/8,7/8,1.0] instead of [5/4,3/4,1.0] → less jitter but (sometimes) slightly slower rate increase
4. Min RTT probing is removed
   – L4S gives very short (or zero) queue delay, but min RTT probing may still be needed in reality
5. BW window reduced to 2 RTTs (was 8 RTTs)
   – Warning.. Too short window can reduce performance for app limited traffic
6. BBR mode forced to BBR_PROBE_BW if more than 1 RTT with CE marked packets and in BBR_STARTUP

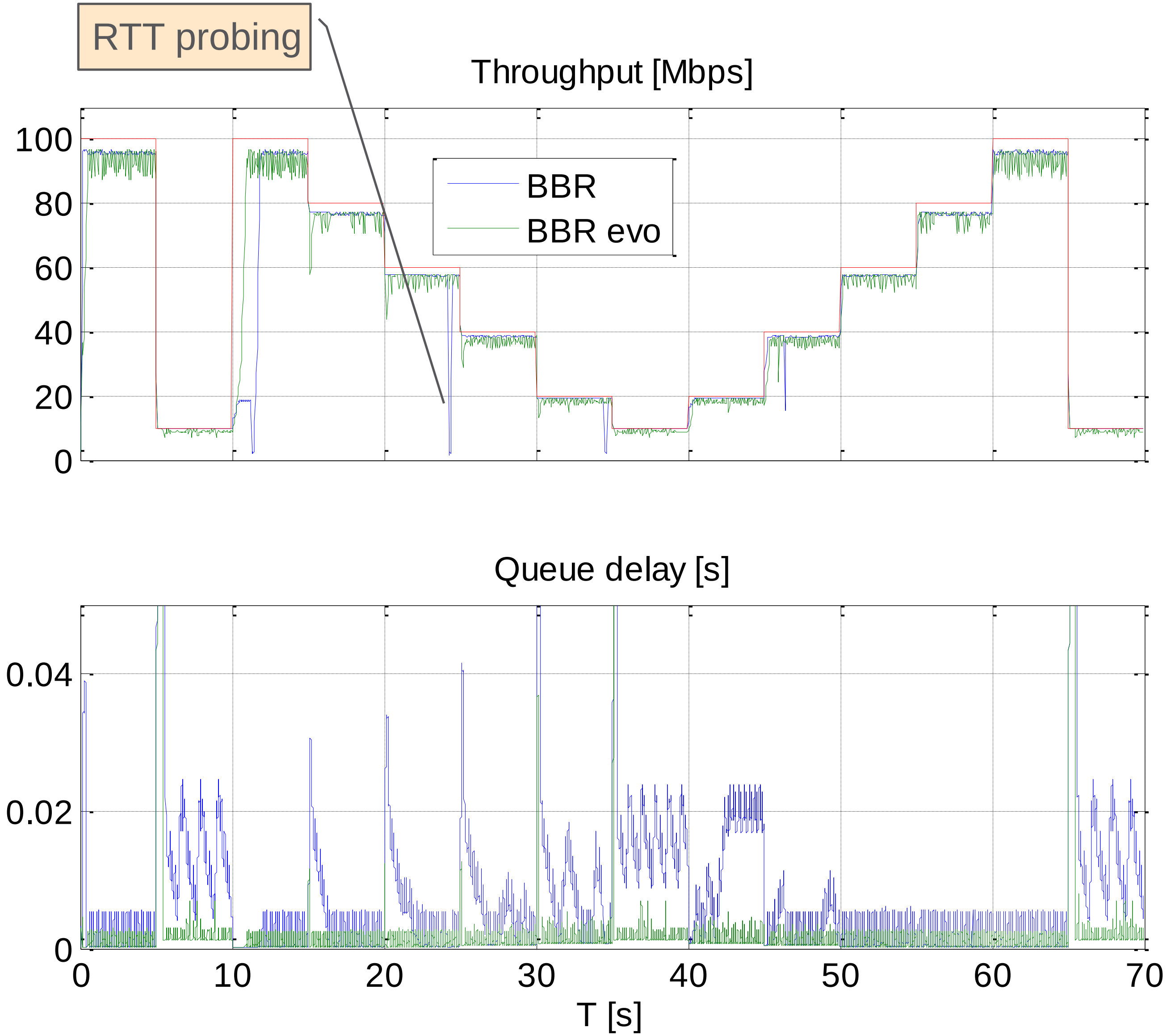
TCP_BBR.C
TCP_INPUT.C
TCP_RATE.C
TCP.H

- Update in function bbr_update_bw(…)
- Additional code in tcp_input.c
  - Added delivered_ce counters
  - Simulilar to delivered counter used with rate sample but only counting CE marked packets

```
/* Estimate the bandwidth based on how fast packets are delivered */
static void bbr_update_bw(struct sock *sk, const struct rate_sample *rs)
{
…

          bbr->round_start = 0;
          if (rs->delivered < 0 || rs->interval_us <= 0)
                    return; /* Not a valid observation */

          /* See if we've reached the next RTT */
          if (!before(rs->prior_delivered, bbr->next_rtt_delivered)) {
…
          }

          bbr_lt_bw_sampling(sk, rs);

          /* Divide delivered by the interval to find a (lower bound) bottleneck
           * bandwidth sample. Delivered is in packets and interval_us in uS and
           * ratio will be <<1 for most connections. So delivered is first scaled.
           */
          bw = (u64)rs->delivered * BW_UNIT;
          bw -= (u64)(rs->delivered_ce >> 2) * BW_UNIT;
          do_div(bw, rs->interval_us);
```

BBR VS BBR EVO COMPARISON

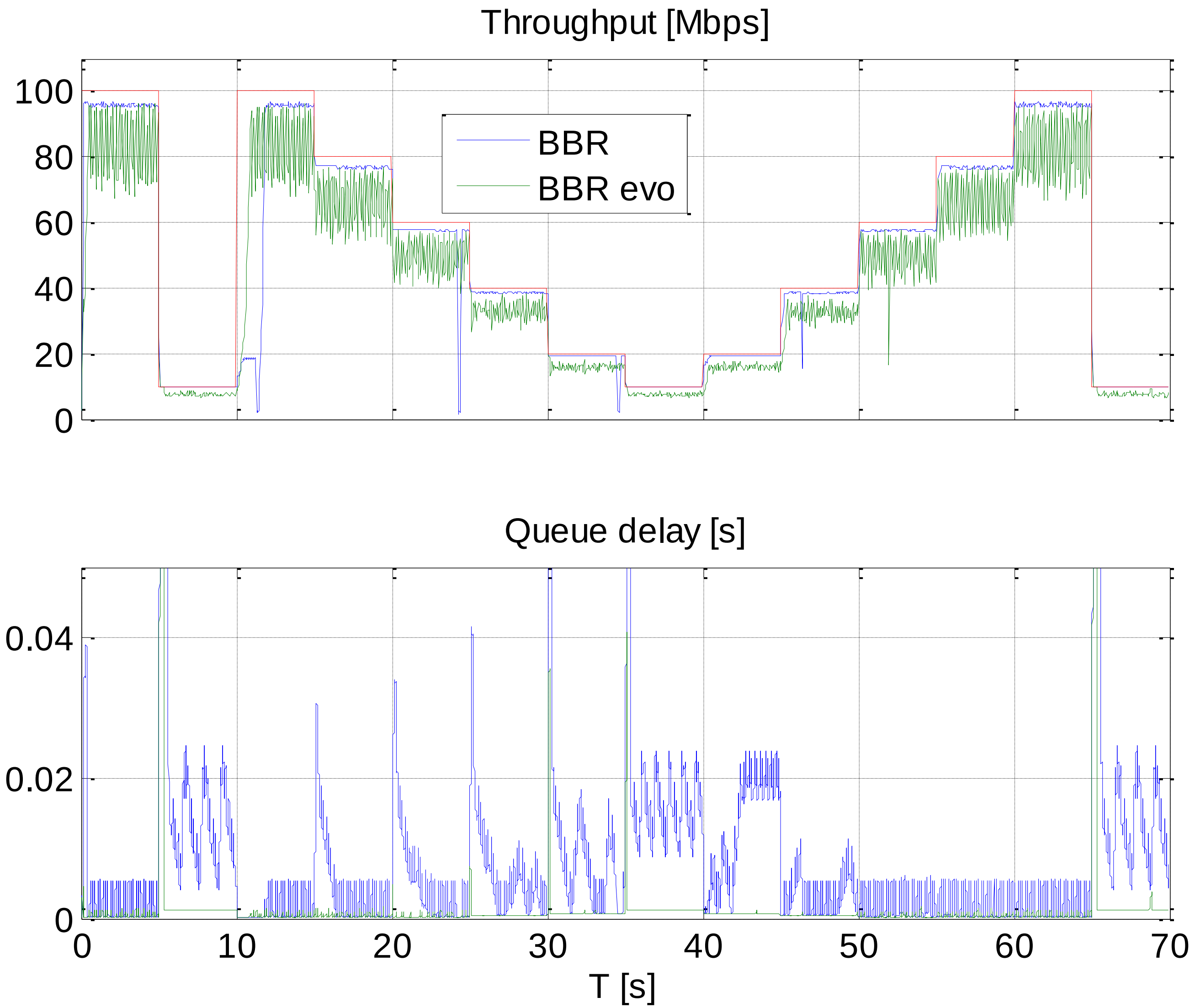
- RTT = 20ms
- L4S mark threshold = 2ms
- BBR evo manages to keep standing queue < 5ms
- BBR has more problems
- BBR evo is slightly slower in the rate increase



Queue delay = Network queue delay

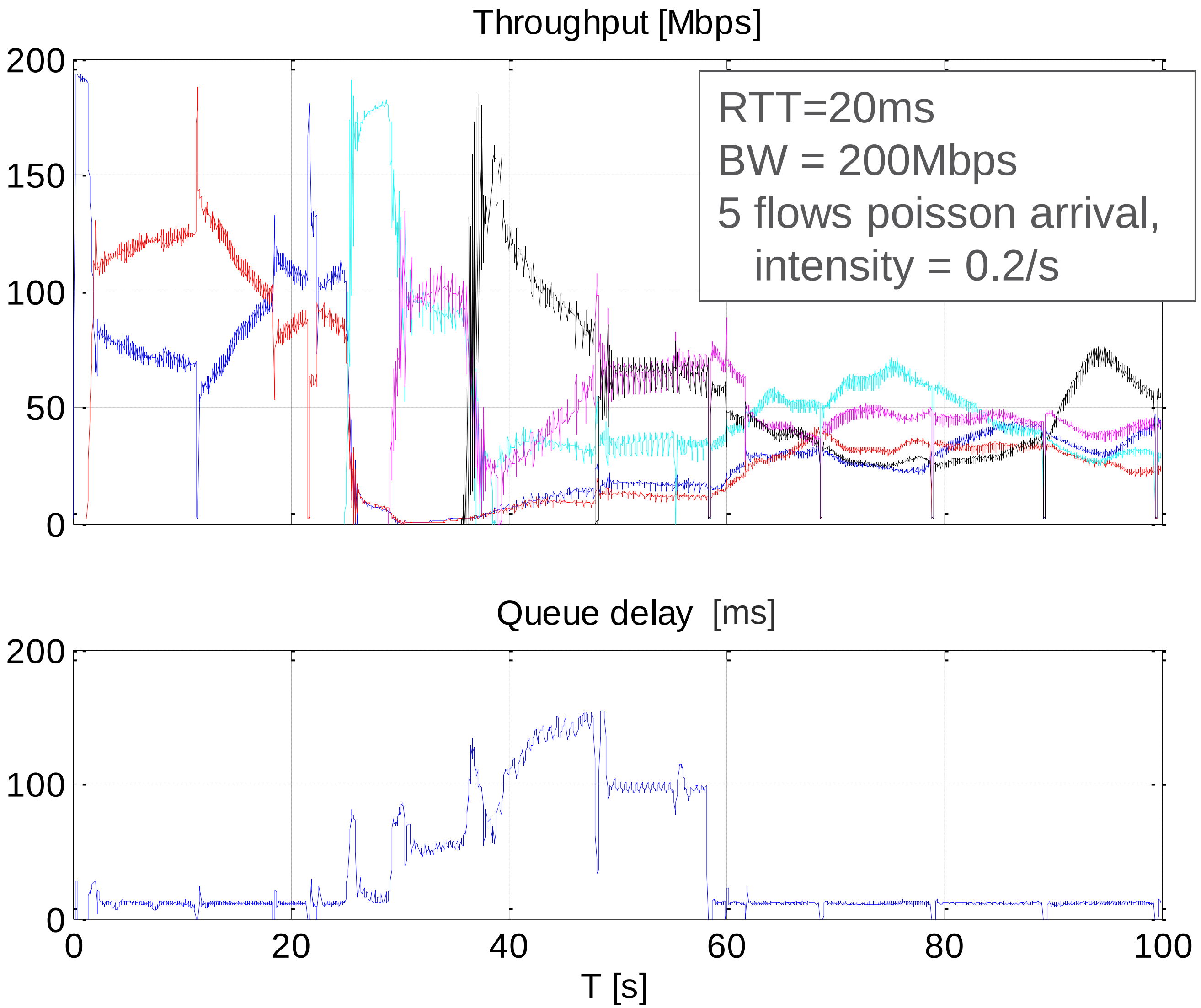
BBR VS BBR EVO COMPARISON
PHANTOM QUEUE

- RTT = 20ms
- Phantom queue
  - L4S mark threshold 95% of BW
  - Measurement period 5ms
- BBR evo manages to keep standing queue < 1ms
- ~10% peak bandwidth sacrificed



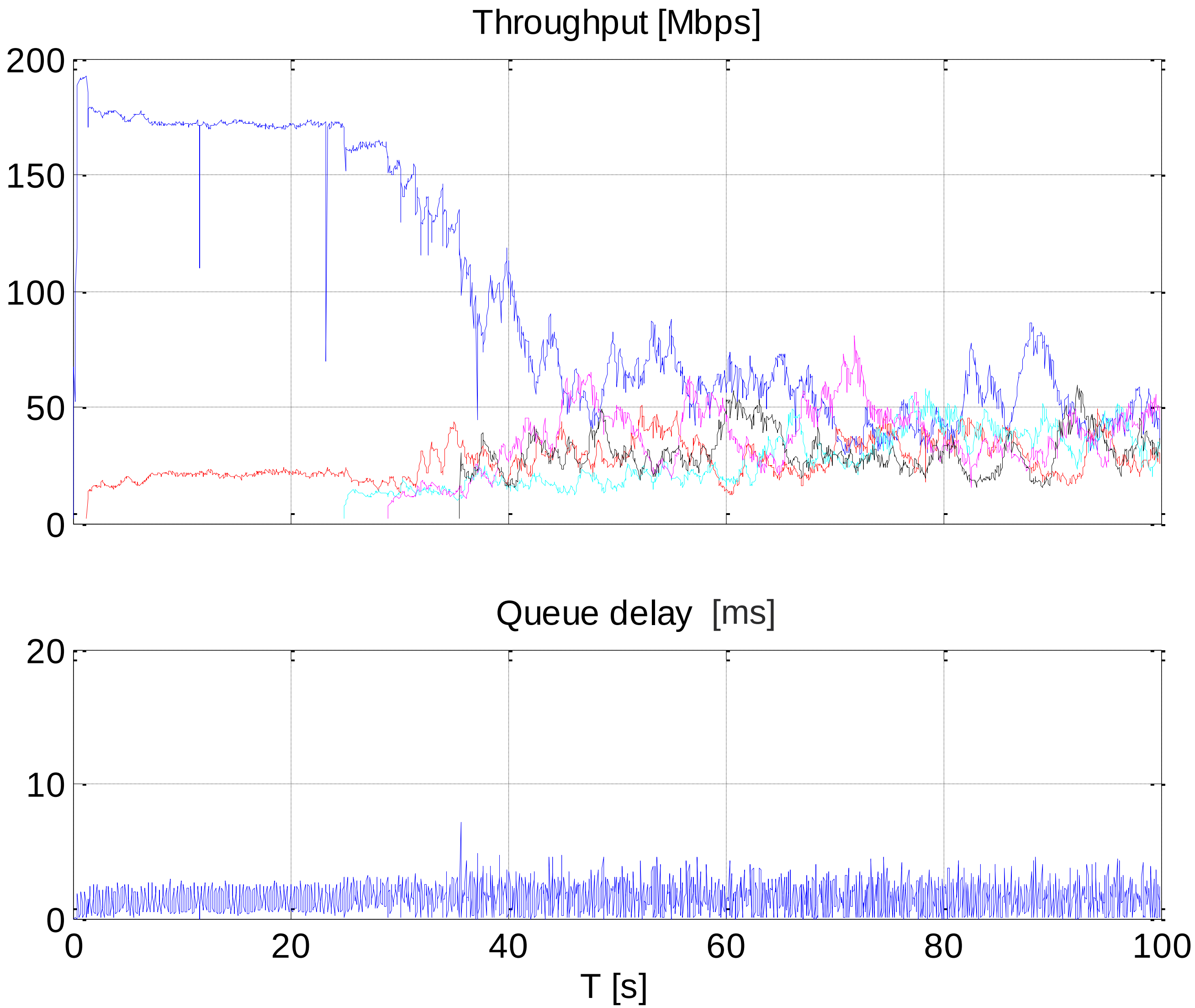
BBR MULTIPLE FLOWS

- Large file transfers
- BBR does not keep standing queue small
  - Mainly an RTT_{min} estimation issue.
- Flow rates converge.. eventually



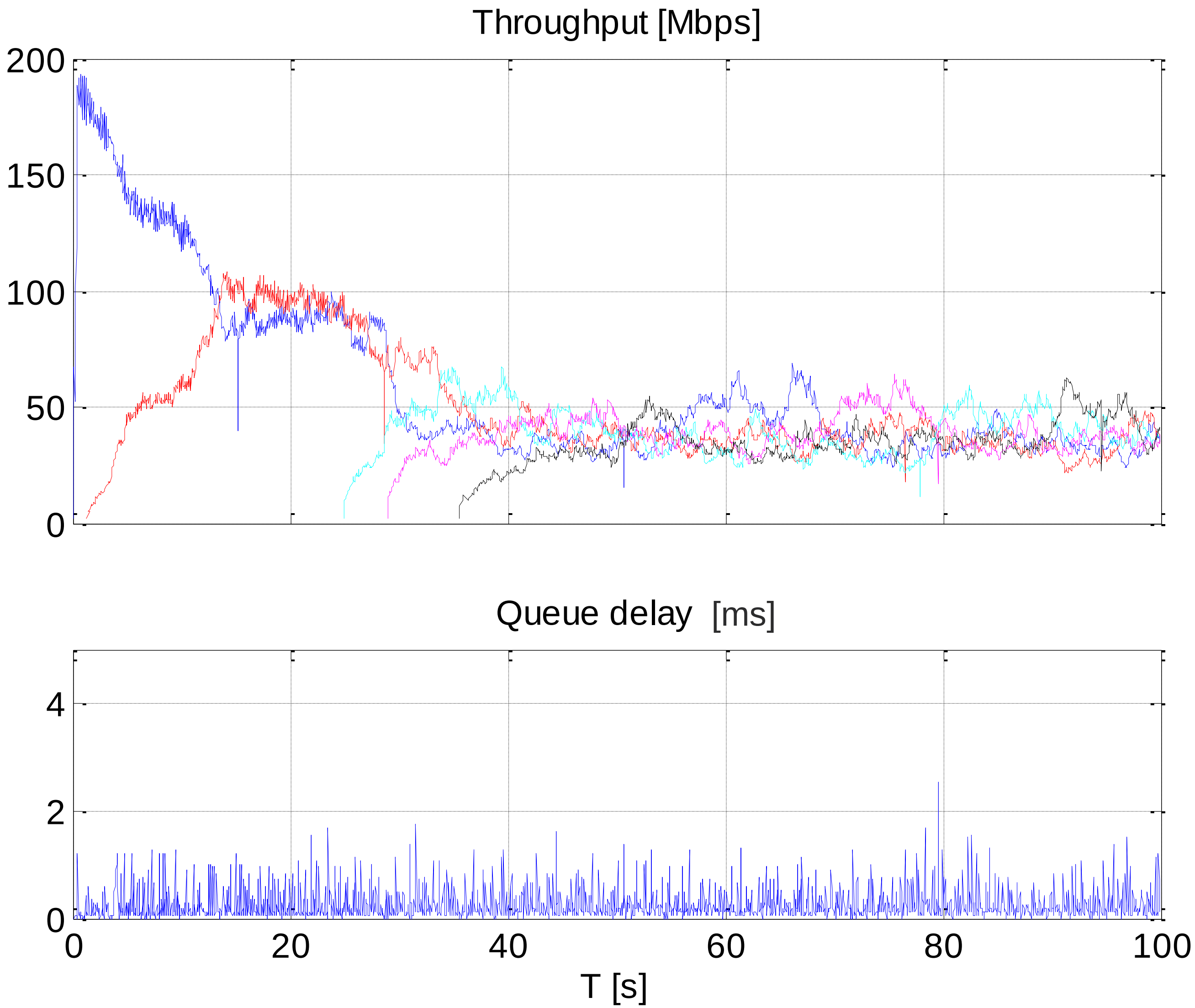
BBR evo MULTIPLE FLOWS

- L4S mark threshold = 2ms
- Quite low queue delay
  - But higher than 2ms threshold
- Reasonably good convergence when new flows arrive
- Newly arrived flows ramp up more slowly



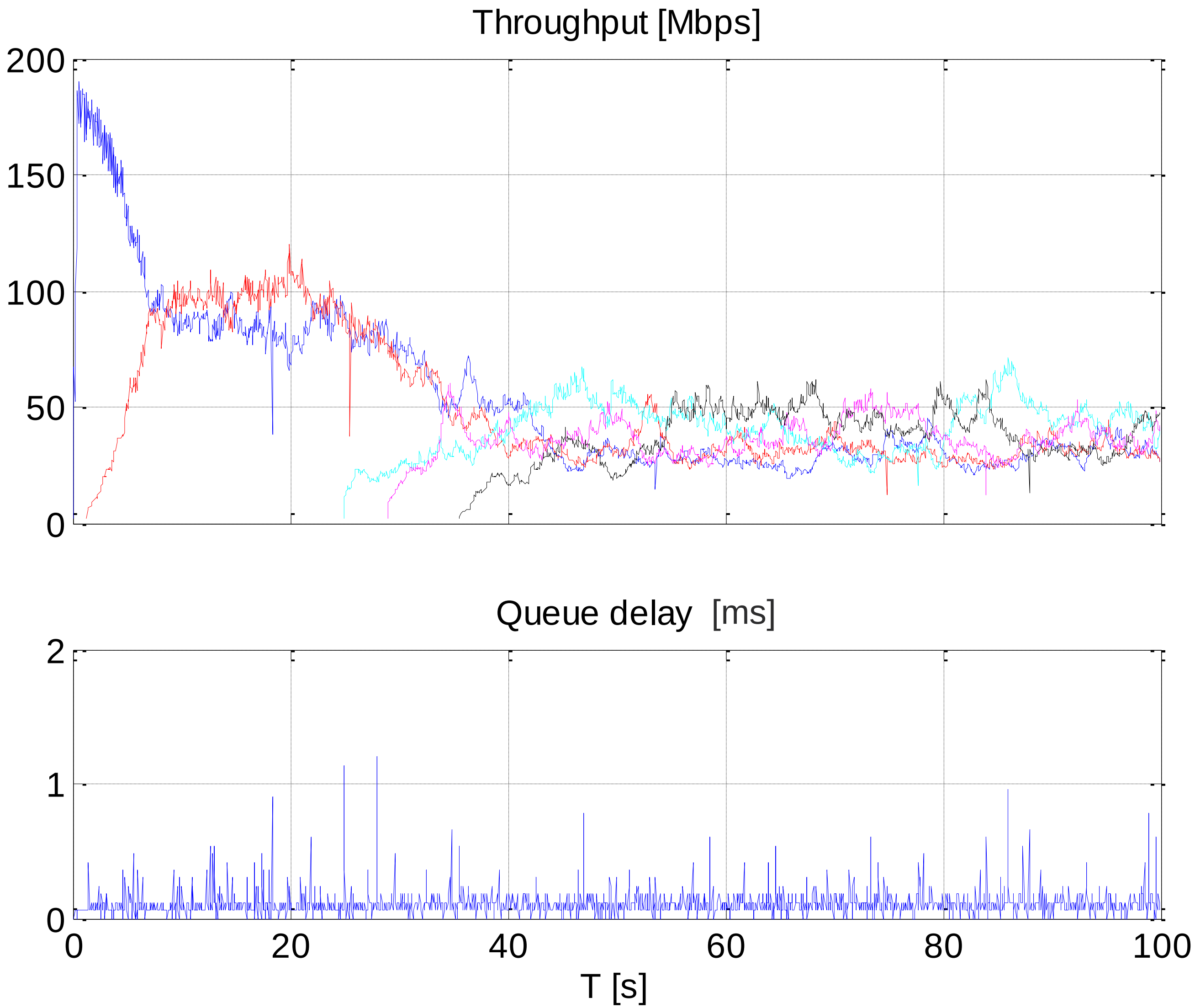
BBR EVO MULTIPLE FLOWS
PHANTOM QUEUE (95%)

› Phantom queue
  – L4S mark threshold 95% of BW
  – Measurement period 5ms
› Very low queue delay
  – But not zero



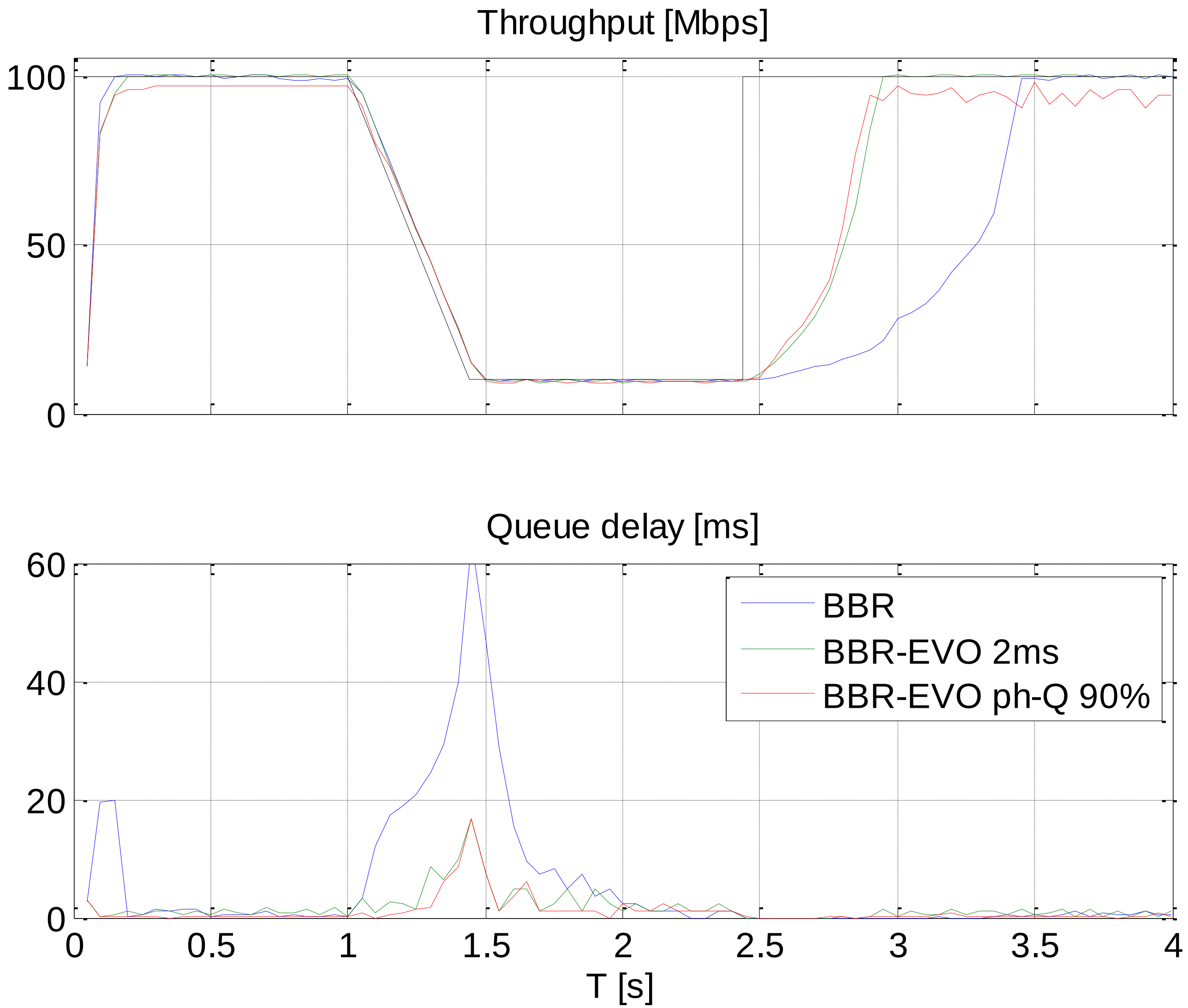
BBR evo MULTIPLE FLOWS
PHANTOM QUEUE (90%)

- Phantom queue
  - L4S mark threshold 90% of BW
  - Measurement period 5ms
- Very low queue delay, but not zero



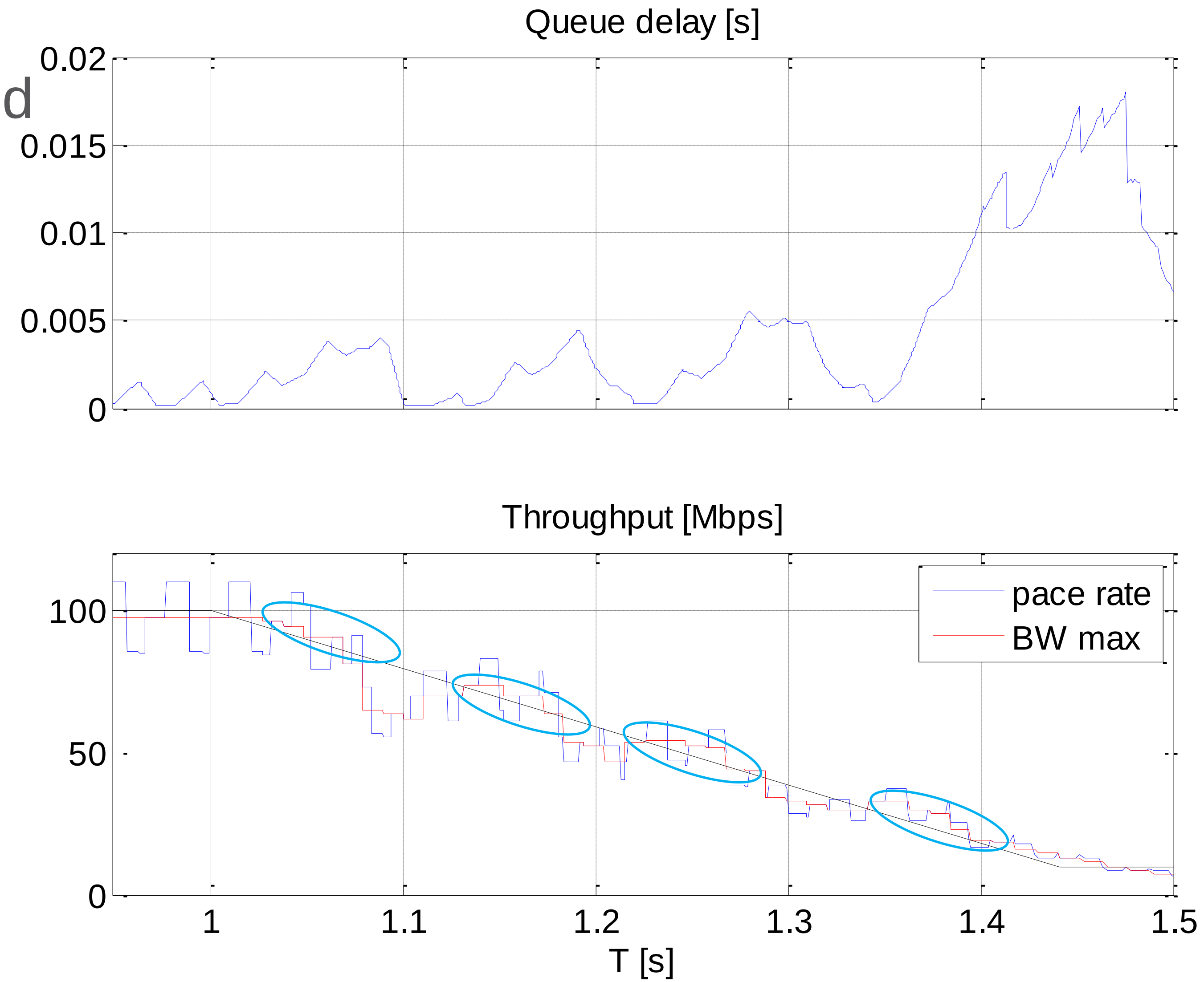
BITRATE RAMP

- RTT = 10ms
- Channel bandwidth reduced from 100 to 10 Mbps in 400ms
- BBR evo reacts better but there is room for improvement
- General problem that throughput is overestimated



BITRATE RAMP, ZOOM IN

- Max BW is slightly overestimated
- More conservative bandwidth probing may help
  - But that can harm flow fairness



RTT FAIRNESS

Throughput ratio
Flow #1 [Mbps]/ Flow #2 [Mbps]

- BW = 100Mbps
- 100s simulation
- TCP flow # 1: RTT = 10ms
- TCP flow # 2: RTT = 10,12,20,30,50ms
- BBR evo: L4S mark threshold = 2ms

RTT flow #2	BBR	BBR evo
10ms	46/50	50/46
12ms	30/65	41/53
20ms	12/82	33/62
30ms	10/90	66/30
50ms	7/87	71/22

RTT FAIRNESS
CONT..

- BW = 100Mbps
- 100s simulation
- TCP flow # 1: RTT = 2ms
- TCP flow # 2: RTT = 2,5,10,15,20ms
- BBR evo: L4S mark threshold = 2ms

RTT flow #2	BBR	BBR evo
2ms	41/55	46/51
5ms	21/75	39/57
10ms	12/84	**92/3**
15ms	6/88	59/37
20ms	7/88	55/40

CONCLUSION

- BBR is quite easy to modify for L4S support
  - But there are probably better ways to do this
- The evolved BBR with L4S support
  - Converges quite well when multiple flows compete for the same bottleneck
  - Keeps standing queue small (or very small with phantom queues)
  - A certain degree of jitter, a result of the necessity to be a bit aggressive in order to achieve convergence for multiple flows

Comments are welcome
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BUZZ WORDS

- BBR = Bottleneck-Bandwidth-RTT
- L4S = Low Loss Low Latency Scalable throughput
- Phantom queue = Link bitrate is measured at e.g. 5ms intervals. Packets are marked when the link bitrate exceeds a given fraction (e.g 95%) of the maximum rate.