National University of Singapore
School of Computing
CS5229: Advanced Computer Networks
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Lecture 4 Training
Rate-based end-to-end Congestion Control

In lecture 4 we studied BBR, a rate-based congestion control algorithm proposed by Google in 2016. BBR uses a simple network model to estimate the BDP and infer congestion. It does so by estimating the bottleneck bandwidth and the minimum RTT, with the later being extremely hard to measure in the wild. A BBR flow can only measure the minimum RTT when the buffer is empty. This becomes impossible when BBR competes with traditional buffer-filling loss-based congestion control algorithms and causes it to *over-estimate* the minimum RTT. This over estimation has been found to make BBR extra aggressive when competing with loss-based flows.

In this training, we will mathematically try to understand the basis of this extra aggression. Consider the network described in Figure 1 where a BBR flow shares a bottleneck with a flow running a toy congestion control algorithm called *Taco*. *Taco* is a very simple congestion control algorithm that **always** keeps 20 packets in the bottleneck buffer. You need to calculate how *Taco*'s 20 packets in the buffer will impact BBR's RTT estimates, and consequently its bandwidth.

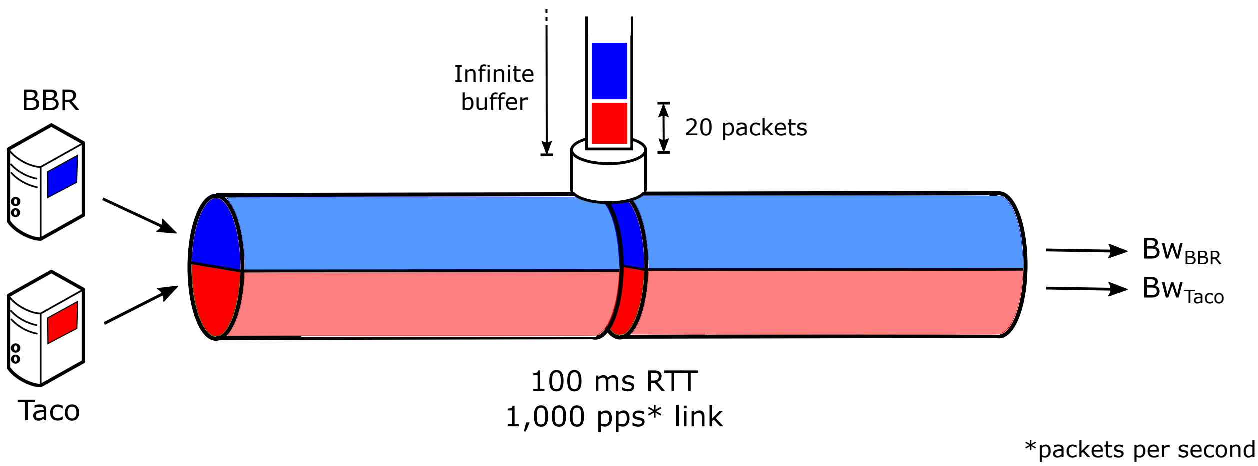

Figure 1: BBR competing with TCP Taco

To help you out, let's recap a key property associated with BBR. BBR's `cwnd` is equal to twice its estimated BDP. Therefore,

$$\mathsf{cwnd} = 2 \times \bar{\mathbf{BDP}} = P_{pipe} + P_{buff} \tag{1}$$

Where $\bar{\mathbf{BDP}}$ is BBR's *estimated* BDP and P_{pipe} and P_{buff} are BBR's packets in the pipe and in the buffer respectively. Also, you can assume that the bottleneck buffer is FIFO and the bottleneck bandwidths received by the flows are directly proportional to their buffer occupancy.

Given these properties, answer the following questions in context of the network described in Figure 1:

1. Assuming the 20 *Taco* packets in the buffer contribute to BBR's RTT over-estimation, how many packets will BBR have in the bottleneck buffer?
2. When BBR does over-estimate the RTT, what is the bandwidth received by the two flows?
3. Let's say the BBR flow is run by an Oracle that knows the true minimum RTT. In other words there is no RTT over-estimation. In such a network, how many packets does the BBR flow place in the bottleneck buffer?
4. When there is no RTT over-estimation, what is the bandwidth received by the two flows?