IETF '87

PIE: A lightweight latency control to address the bufferbloat problem issue

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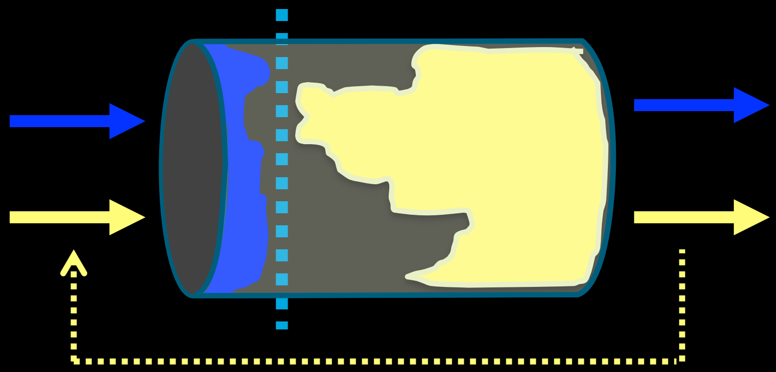
July 30, 2013

The Problem of Buffer Bloat

- Causes of the buffer bloat:
  - Sheer volume of Internet traffic: explosion of internet traffic
  - Cheap memory: customers want more memory to avoid packet drops
  - Nature of TCP: the TCP protocol can consume all buffers available
  - No efficient queue managements: no simple and effective algorithms
- Lack of a robust, consistent solution will cause:

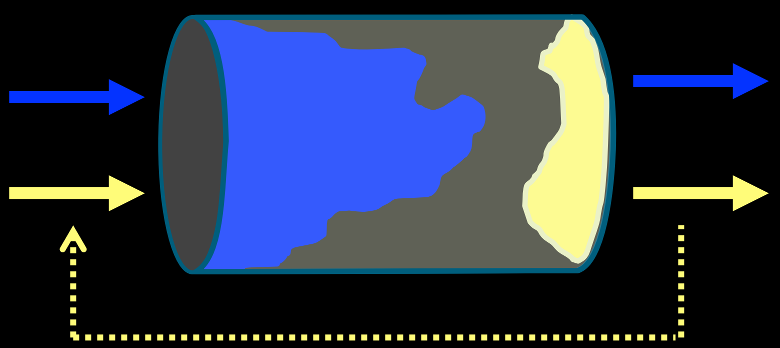
Control Average Delay and Allow Big Burst

Current Design



- Large TCP flows occupy most buffer
- Feedback signals are sent when buffer occupancy is big
- Average delay is consistently long
- Little room left for sudden burst

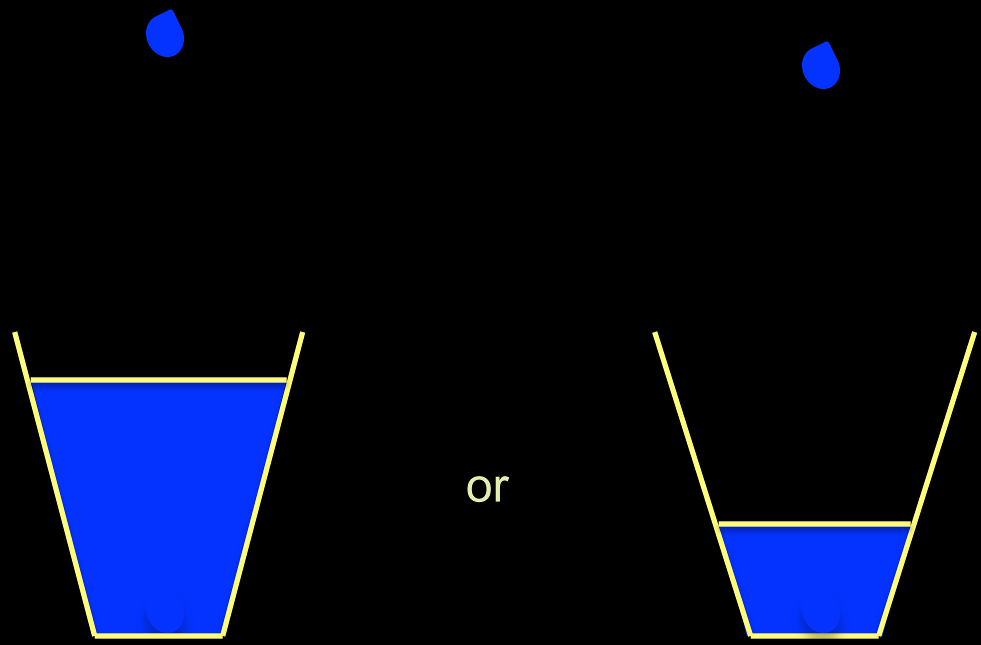
Future Goal



- Large TCP flows occupy small buffer
- Feedback signals are sent early
- Average delay is kept low
- Much room left for sudden burst

Water Level in a Leaky Bucket: An Analogy

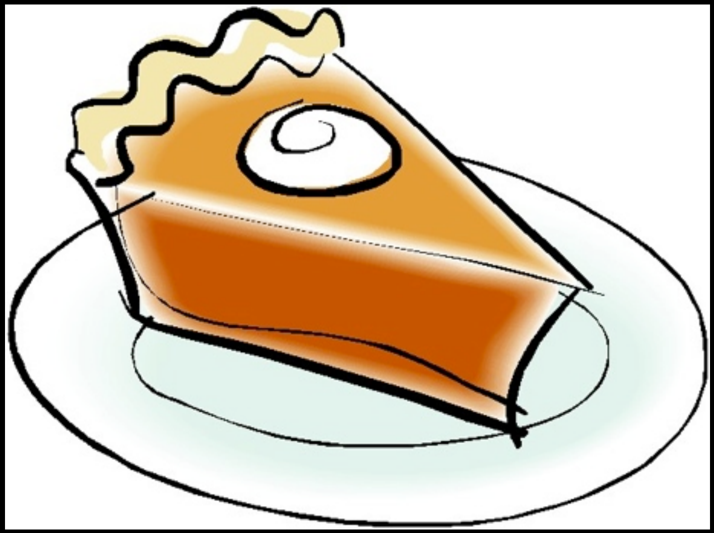
water level can
stay high
If arrival rate =
departure rate



water level can
also kept low if
arrival rate =
departure rate

big buffer (bucket size) does not have to imply
high average delay (standing water level)

Solution Maybe



As Easy As PIE!

Goal #1: Controlling Delay instead of Queue Length

- Control latency instead of queue length
  - Queue sizes change with link speed and estimation of RTT
  - Delay is the key performance factor that we want to control

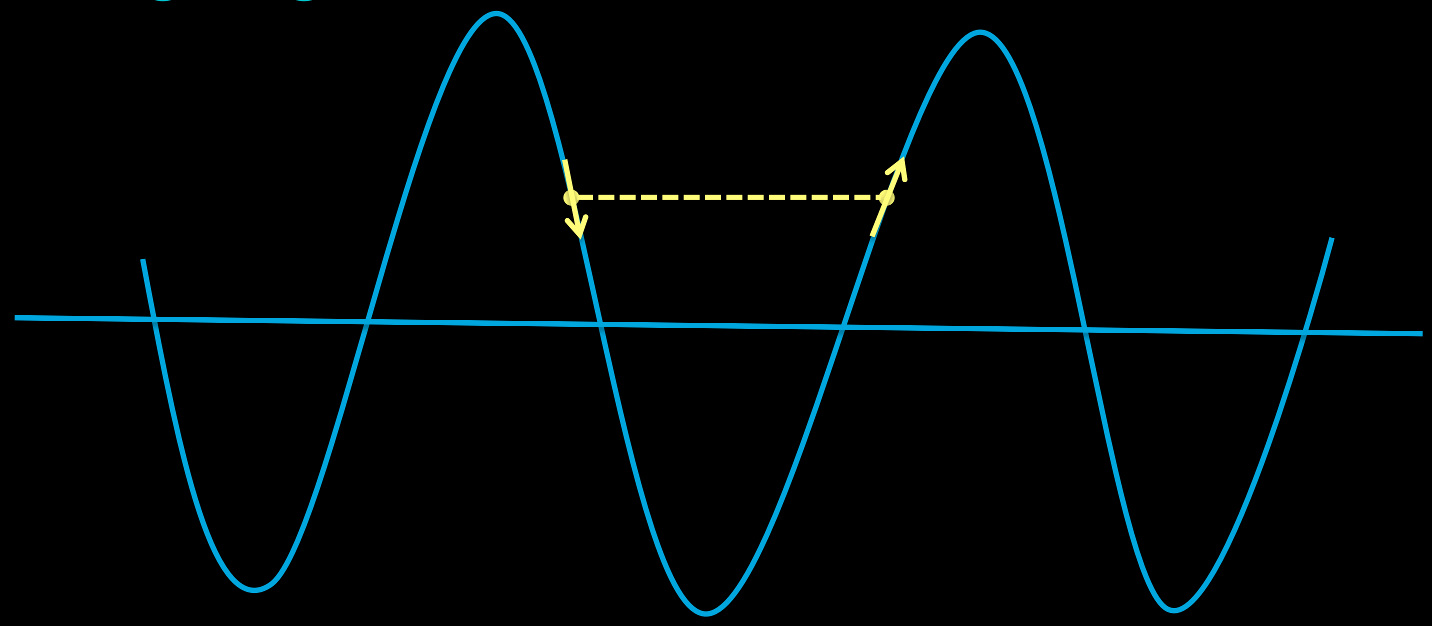
- Delay bloat is really the issue. If delay can be controlled to be reasonable, buffer bloat is not an issue. As a matter of fact, a lot of customers want MORE and MORE buffers for sudden bursts

Goal #2:
Simple Design and Low Operational Overhead

- Design a drop-at-enque algorithm like RED
  - Drops at deque are costly and waste network resources
  - Make deque timing unpredictable

- The algorithm should be simple, easily scalable in both hardware and software
  - Need to work with both UDP and TCP traffic

Goal #3:
Achieving High Link Utilization and Maintain Stability



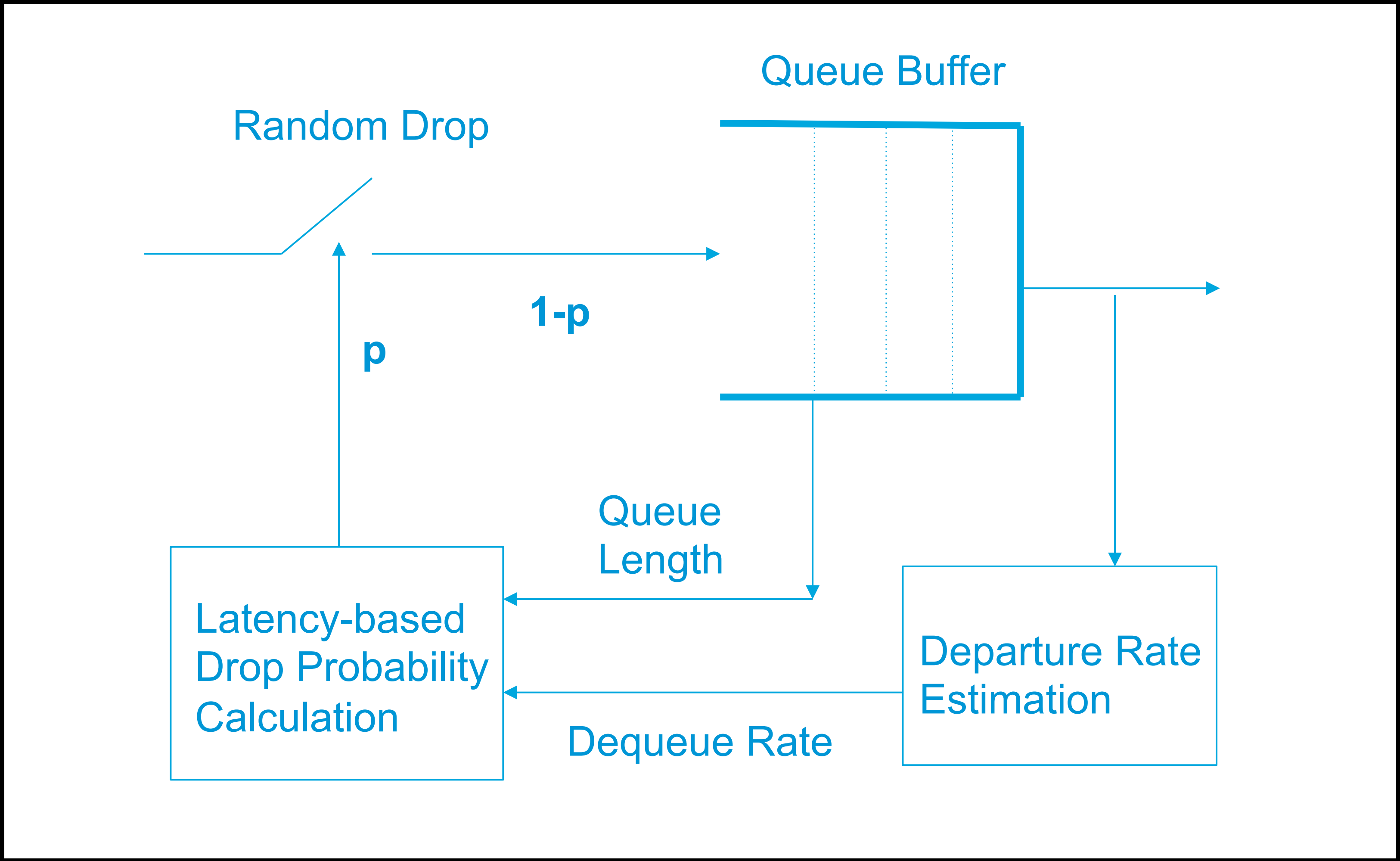
- Traditionally drops/marks increase as the queue lengths increase (longer delays), which could result in wide swing delay variation
- Crucial! Knowing the direction of the changing latency, we can increase stability and modulate the drops/marks intensity to reduce latency and jitter.

The design of PIE

a and b are chosen via control analysis

- Upon every packet arrival
  - randomly drop a packet based on drop_prob calculated below
- Every T_{update} interval
  - estimated_delay, est_del = queue_length/depart_rate
  - drop_prob += a*(est_del – target_delay) + b* (est_del – est_del_old)
  - est_del_old = est_del;
  - depart_count = 0;
- In a measurement cycle
  - Upon a packet's departure: depart_count += deque_packet_size;
  - if dq_count > deq_threshold then
  -     depart_rate = deqart_count/(now-start);
  -     dq_count = 0; start = now;

The block diagram of PIE



PIE's Work Update (based on community's feedback)

- Fixed PIE's initialization issue with very slow speed links
  - in slow speed links, original PIE may not get a valid rate measurement in one update interval, fixed the bug
- Fixed the initialization behavior of One single TCP with long RTT
  - original PIE is fragile in the above scenario. Added robustness into the design

PIE's Summary and Future Work

- Simulation results, testbed experiments and theoretical analysis show that PIE is able to
  - Control low latency across different applications
  - Simple to implement
  - Achieve high link utilization and maintain stability across various traffic scenarios
  - Self tune its parameters

- Future work: further simplify PIE, class-based PIE

Thank you.