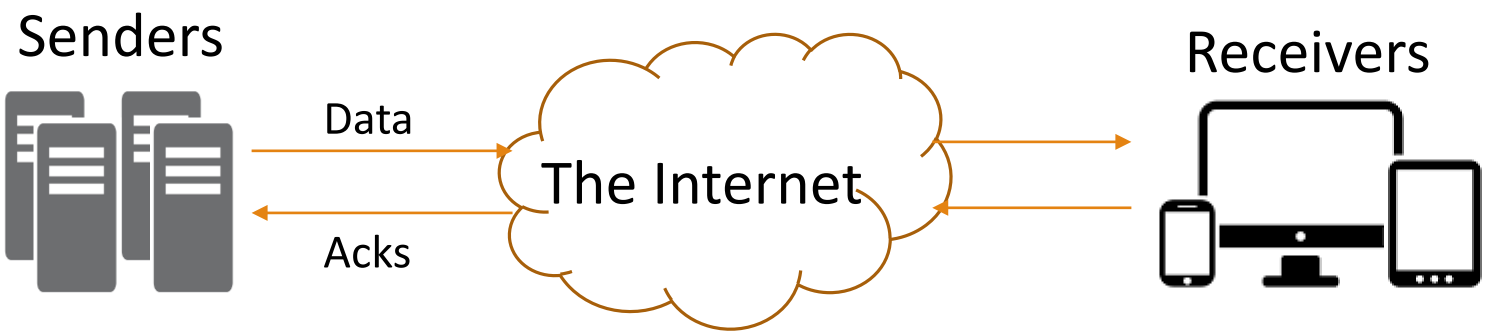
A PCC-Vivace Kernel Module

PRESENTED BY TOMER GILAD

Internet Congestion Control



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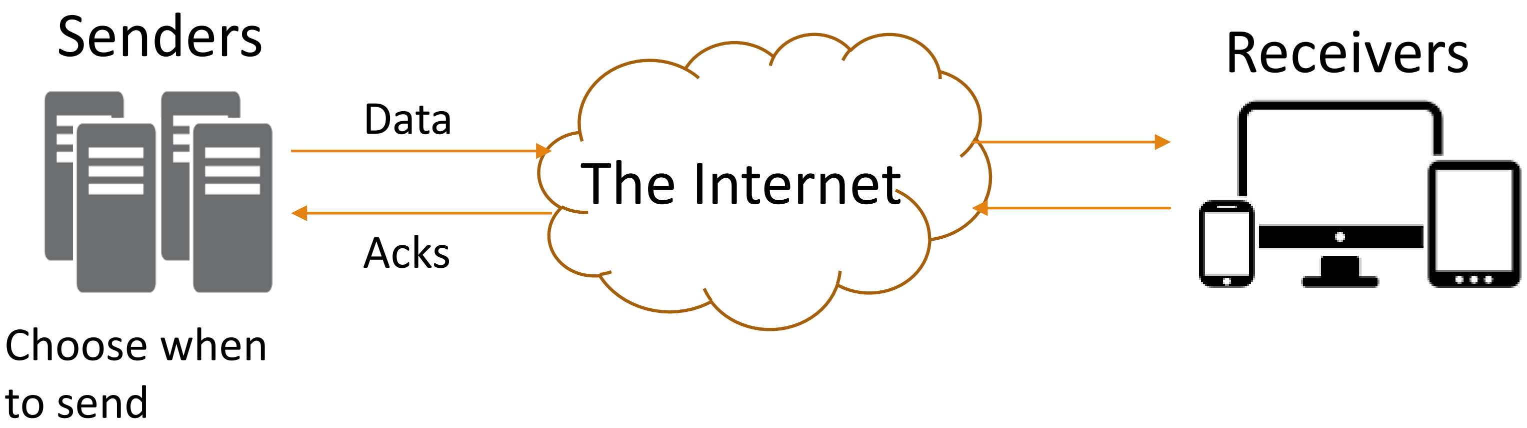

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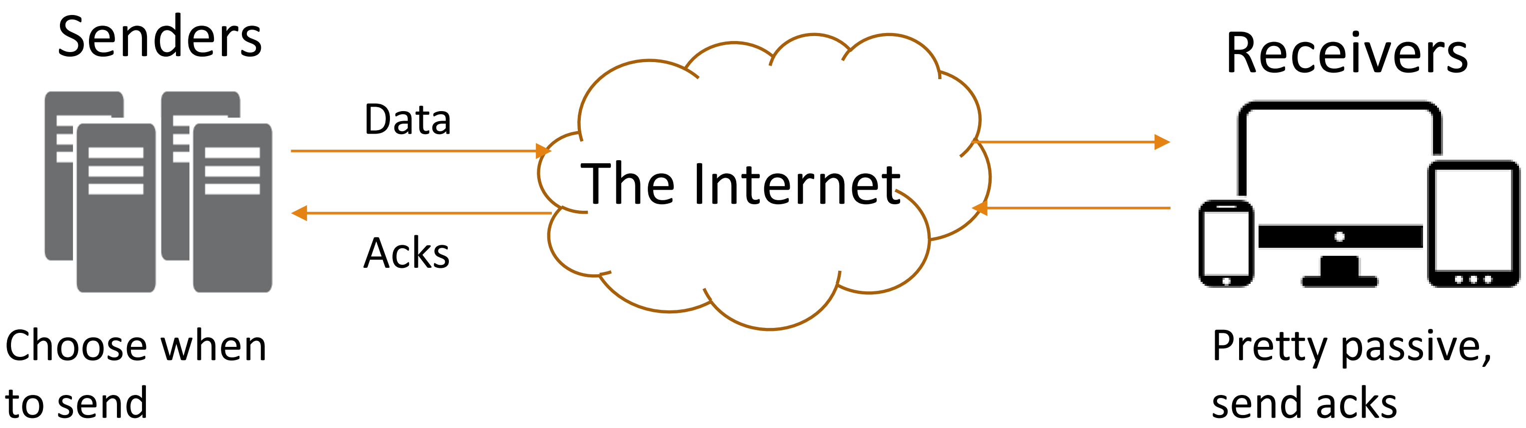

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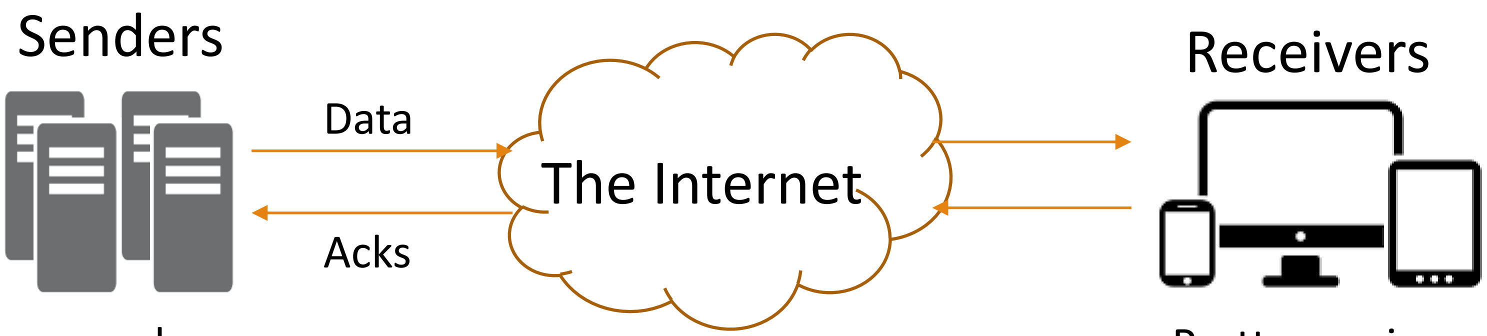

Choose when to send

Tries to get packets through but…

Pretty passive, send acks

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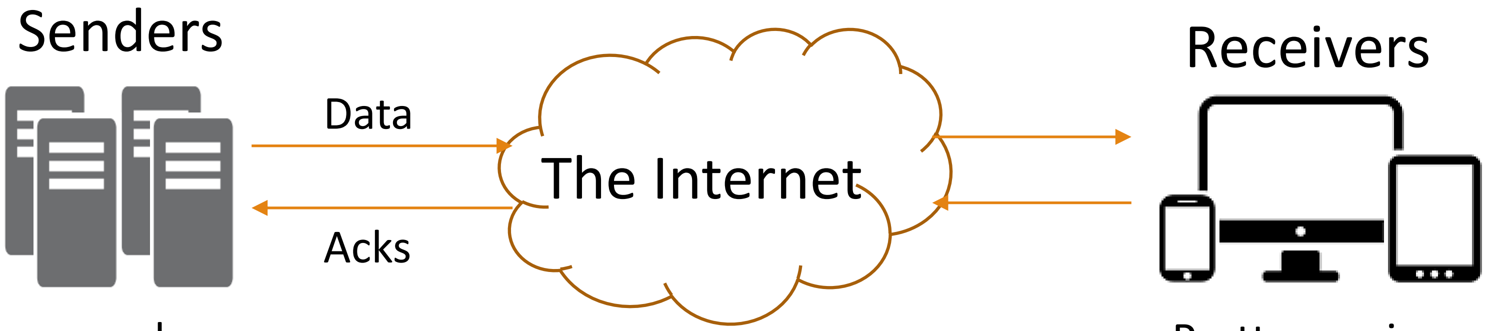

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small buffers
large buffers
random loss
competing flows
WiFi links
LTE links

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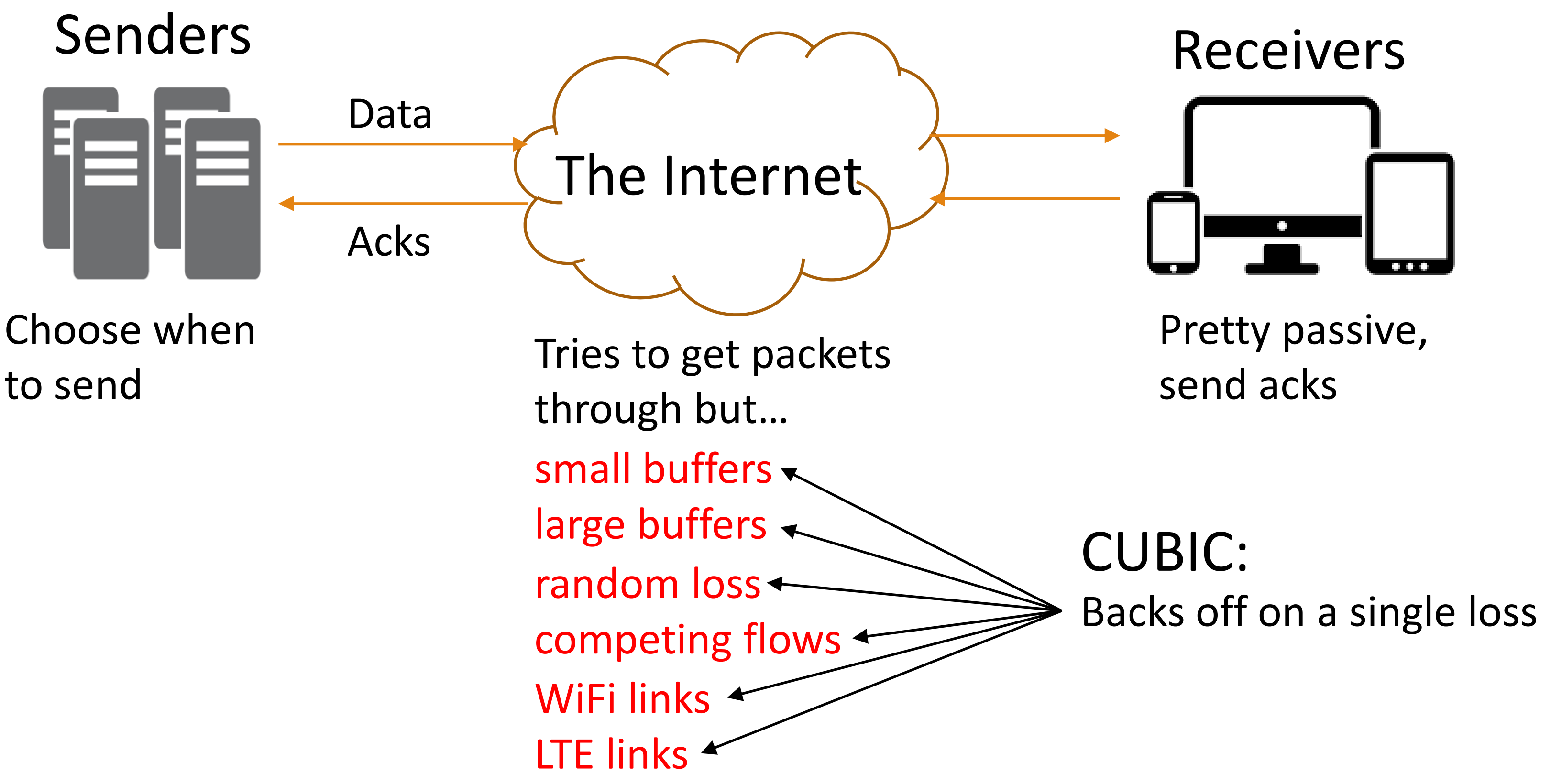

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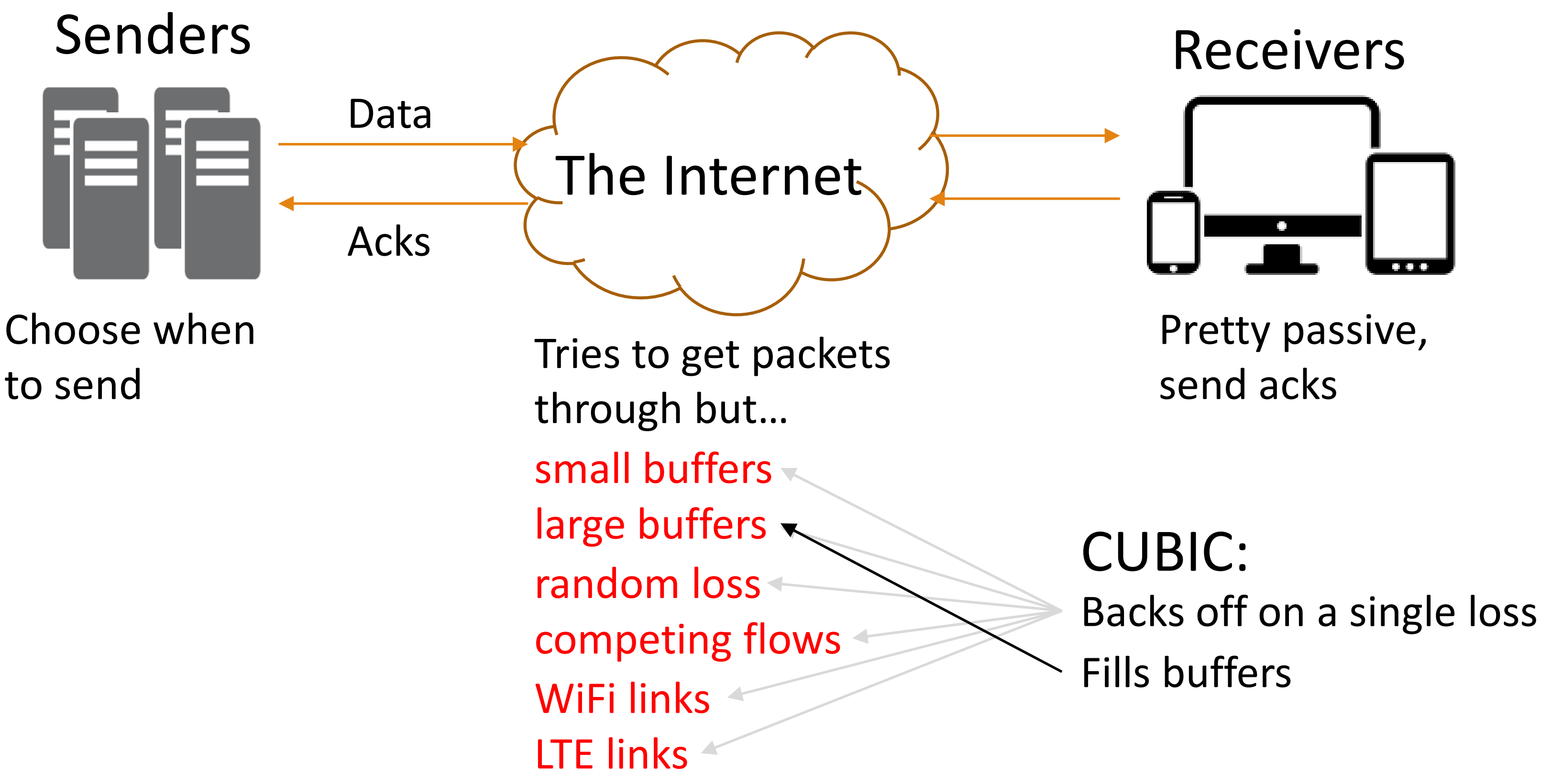

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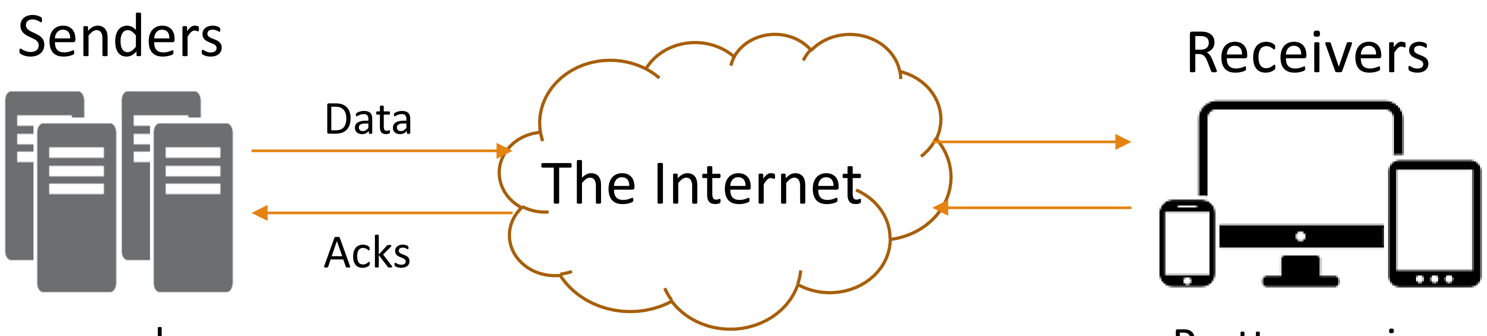

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Explicit model, better performance

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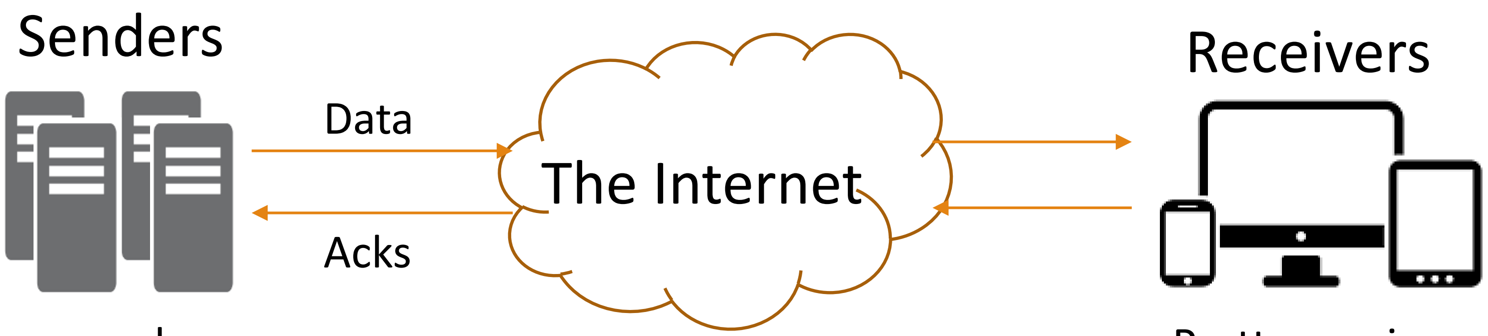

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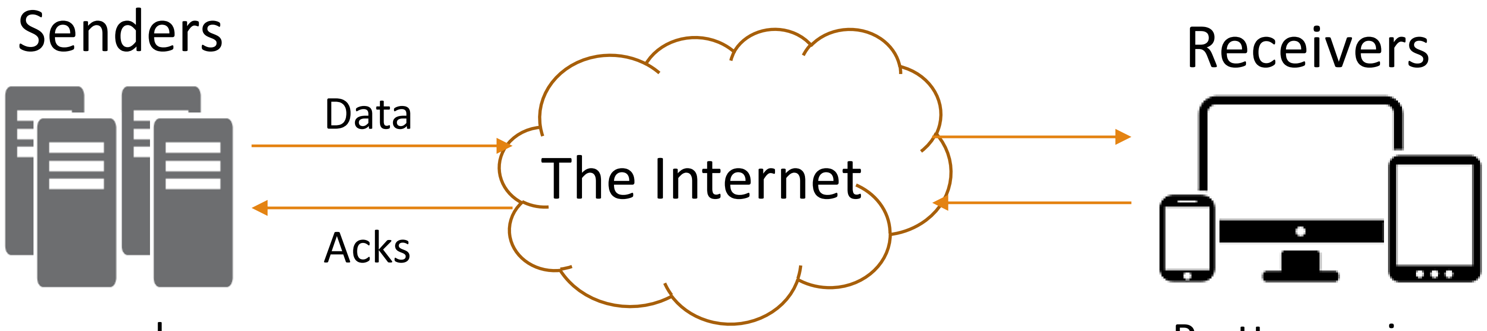
BBR:
Explicit model, better performance
Fills to limited extent, drains periodically
High loss rate

Internet Congestion Control



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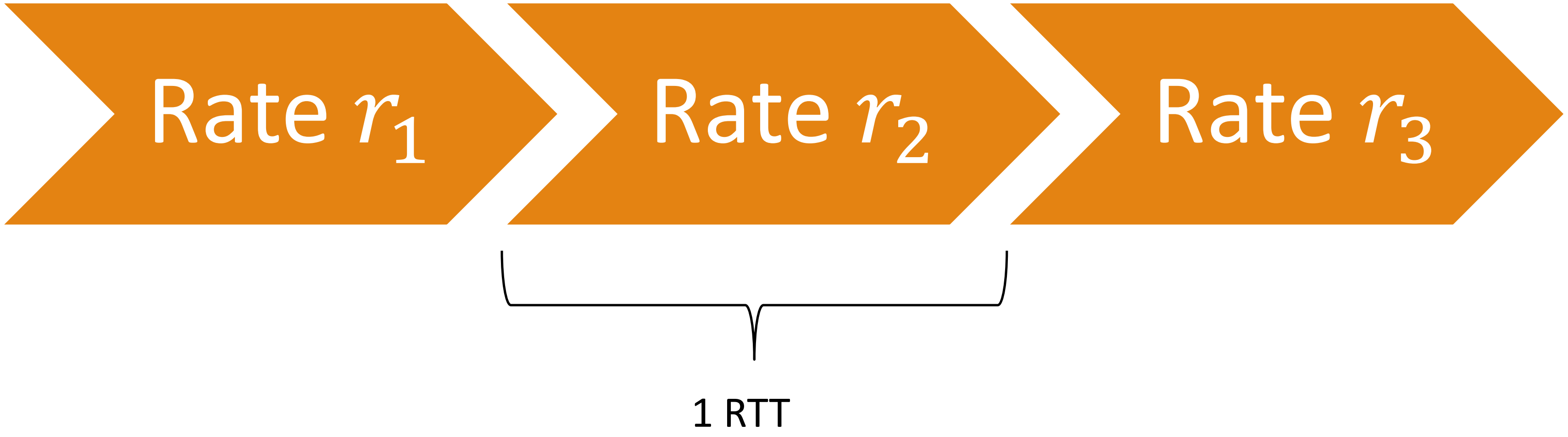
PCC:

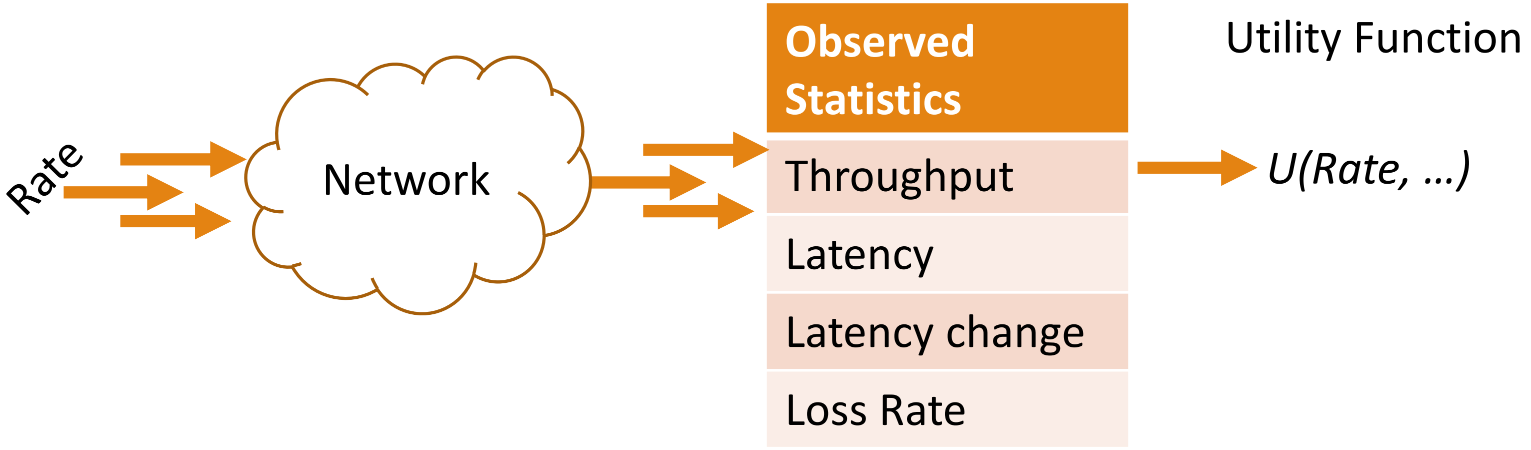
1. Monitor performance at various rates
2. Adapt rate in the utility-maximizing direction

PCC Utility Framework

PCC uses monitor intervals



PCC Utility Framework



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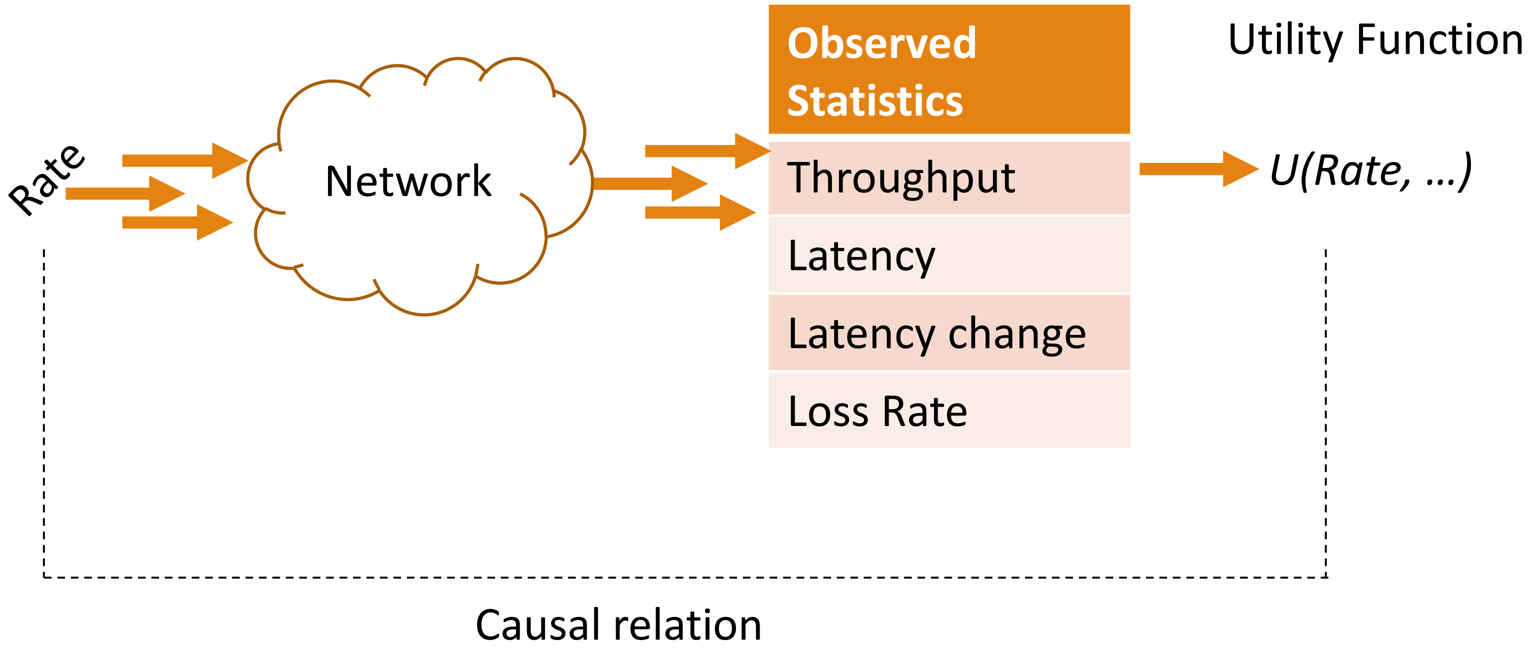

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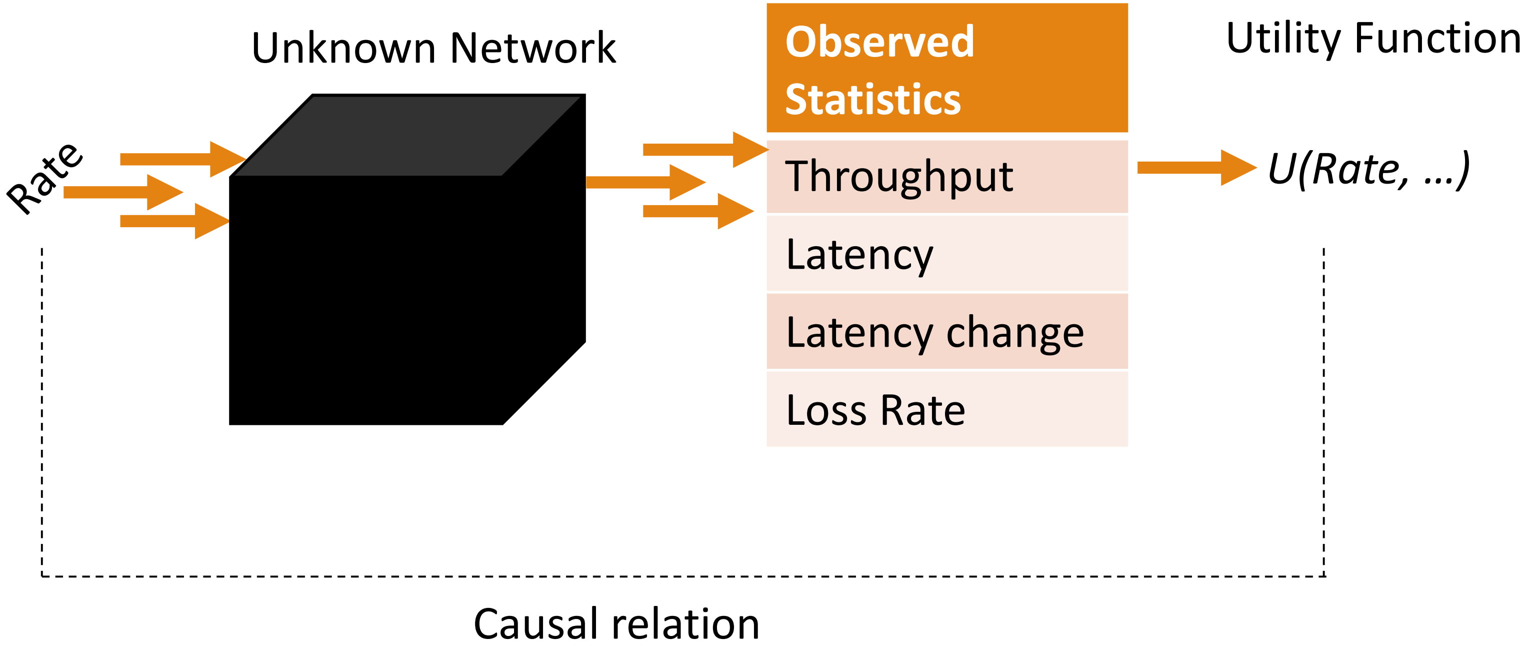
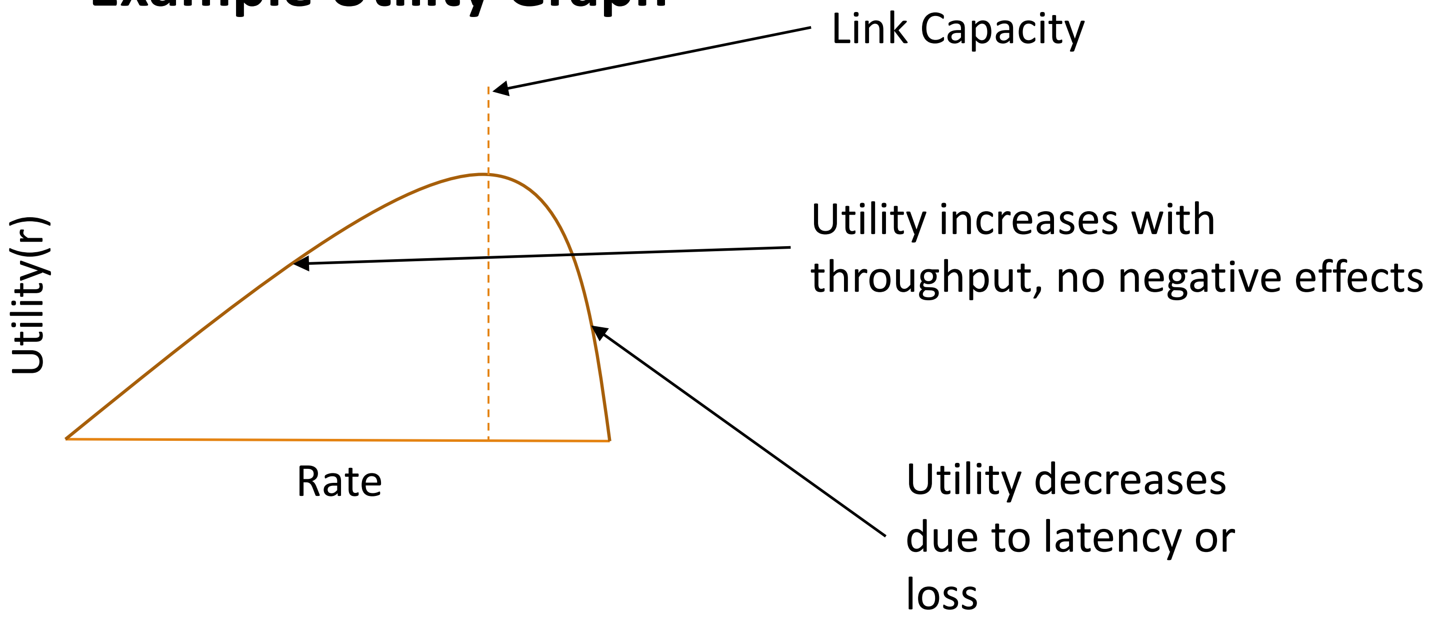


PCC Utility Framework

Example Utility Graph



PCC Flexibility

We give two utility functions, Allegro and Vivace

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$$\mathrm{U}_A(r) = \frac{r}{1+e^{100L}} - rL$$

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Positive reward diminishes with loss rate.

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Positive reward diminishes with loss rate.

Penalty factor for loss.

$$U_A(r) = \frac{r}{1+e^{100L}} - rL$$

PCC Flexibility

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$$\mathrm{U}_V(r) = r * (1 - \alpha\frac{dRTT}{dt} - \beta L)$$

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Unit reward for sending

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Reward or penalty based on rate (will give a nice gradient)

Penalty factor for latency inflation. Can be extremely high to react quickly.

PCC Flexibility

We give two utility functions, Allegro and Vivace

Penalty factor for loss. Determines maximum random loss allowed.

Unit reward for sending

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Reward or penalty based on rate (will give a nice gradient)

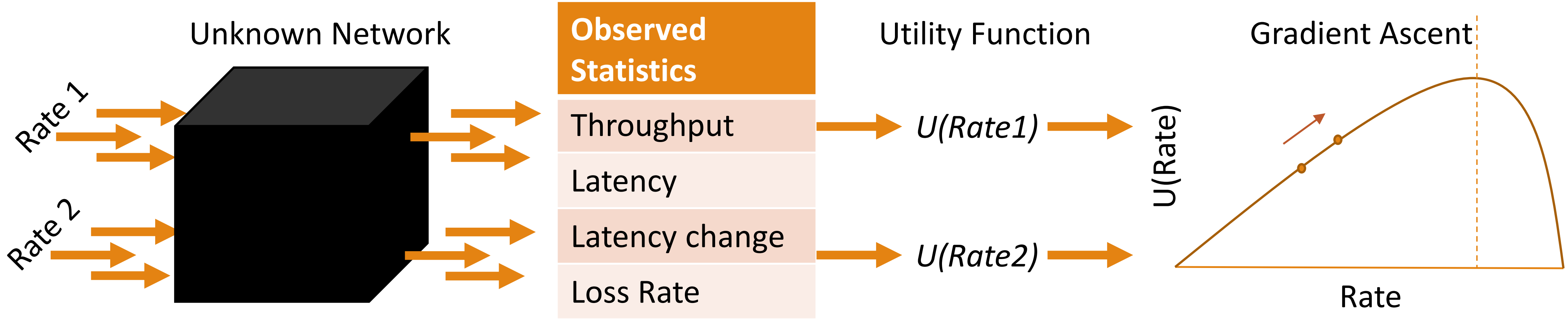
Penalty factor for latency inflation. Can be extremely high to react quickly.

PCC Flexibility

Other functions may work with other features:

- Functions based on jitter may work as scavengers
- Using latency directly on paths with known low-latency may give latency guarantees
- Maybe using latency directly to keep queues slightly full

PCC Rate Control



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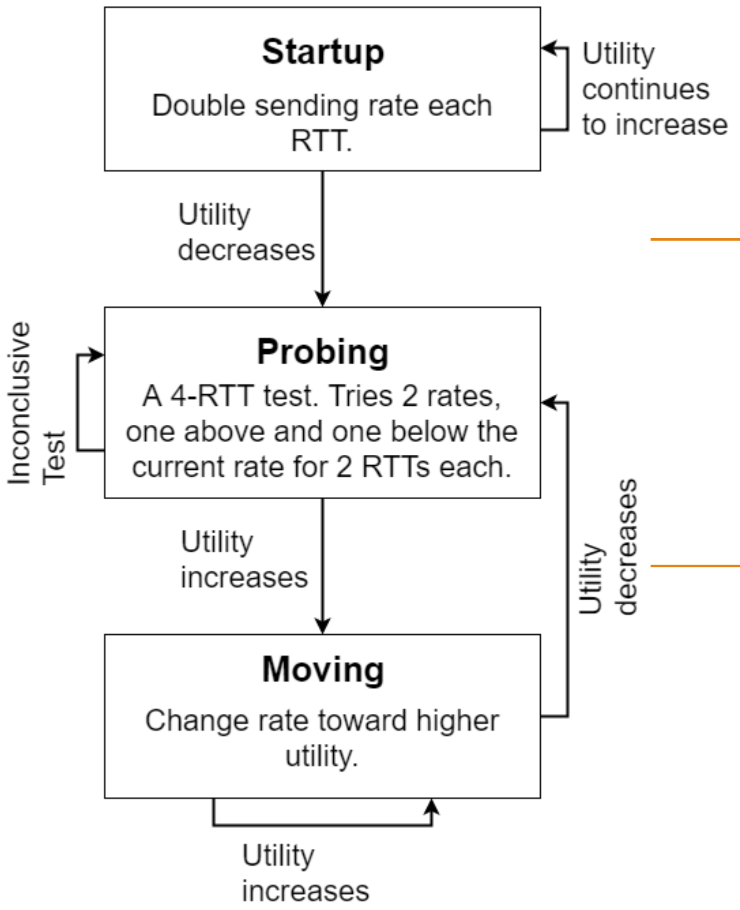
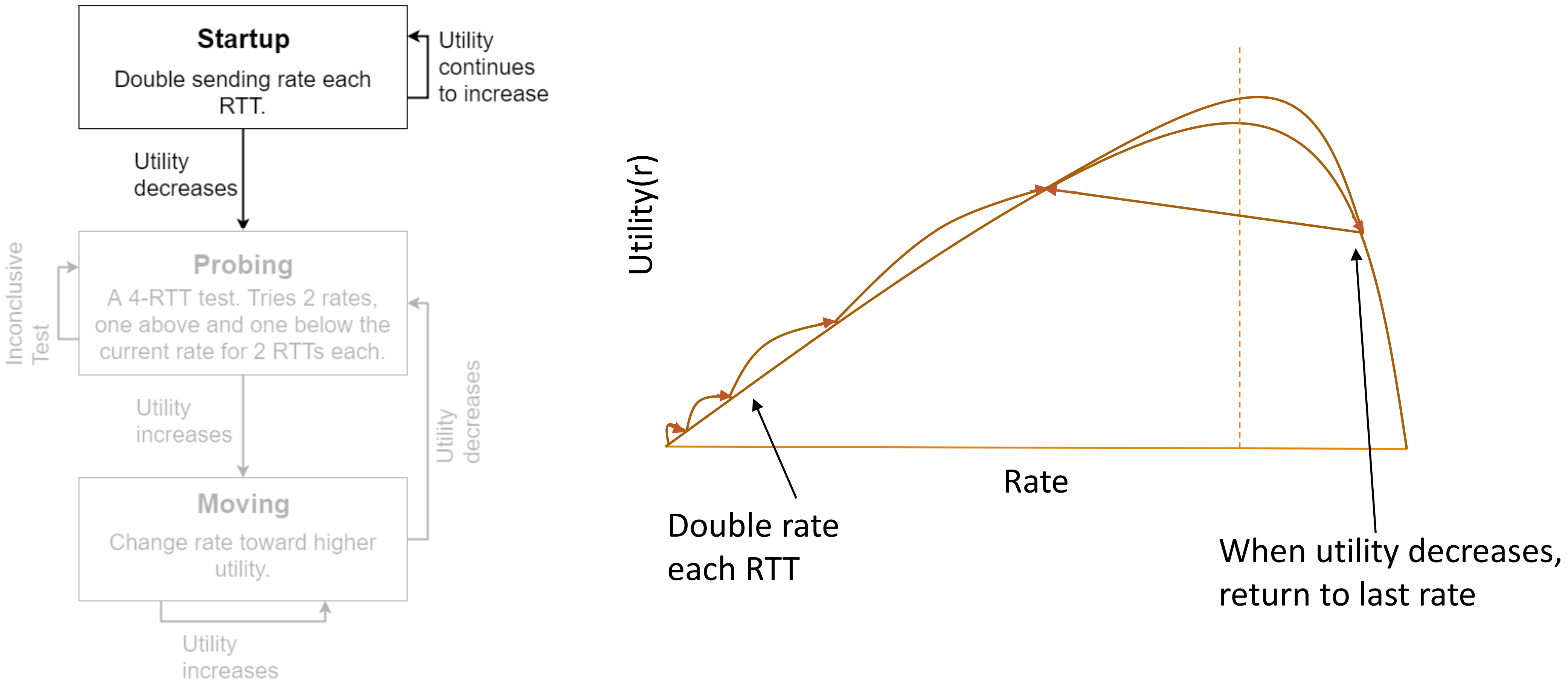


Quickly reach within 50% of link capacity

Determine direction of increasing utility

Quickly move toward greater utility

PCC Rate Control



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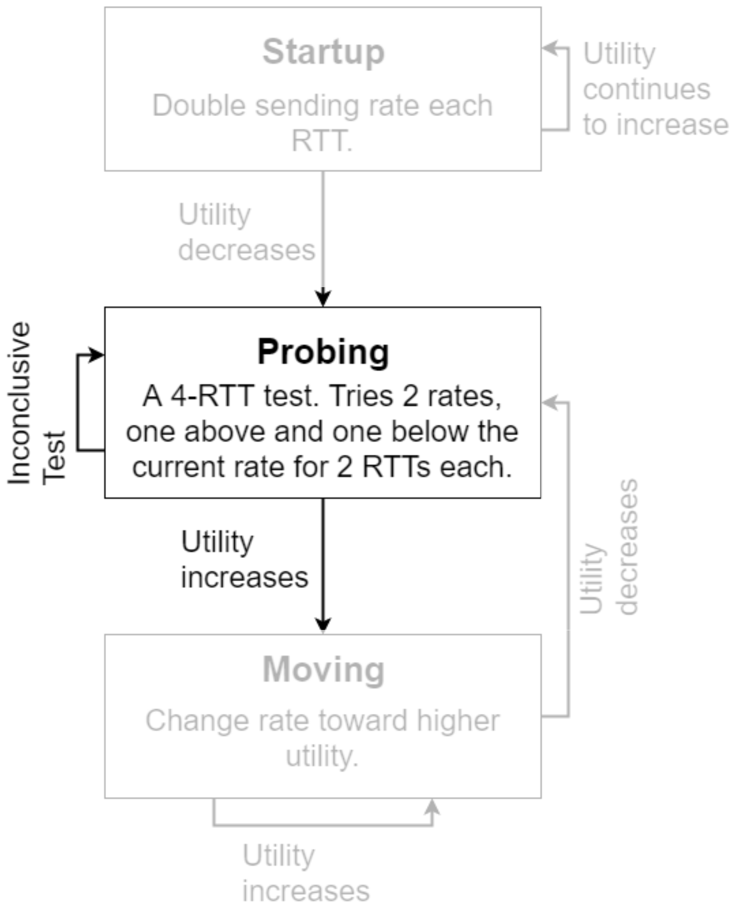

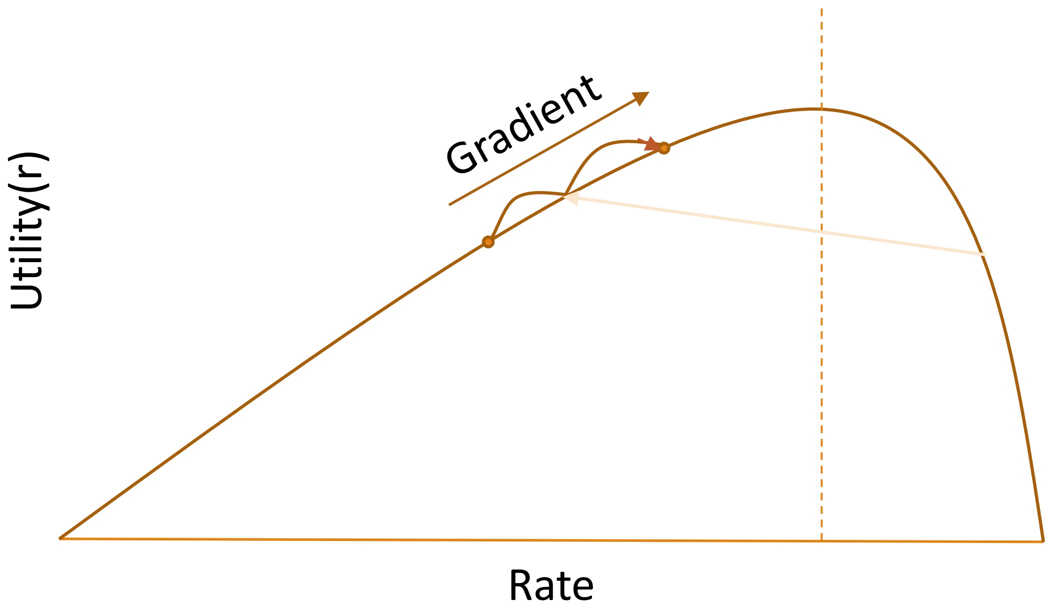

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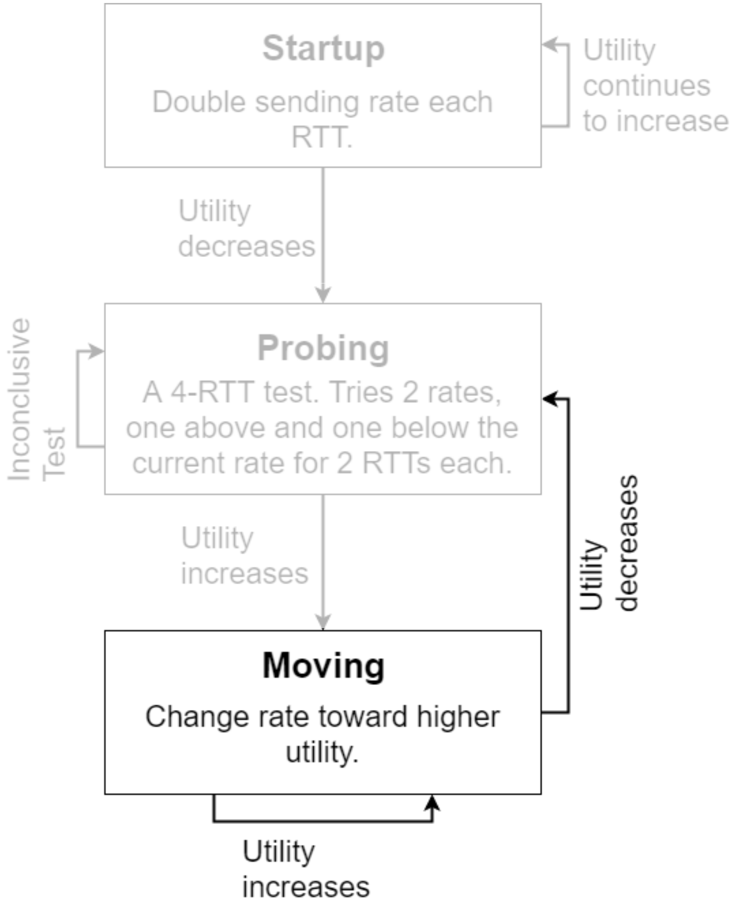
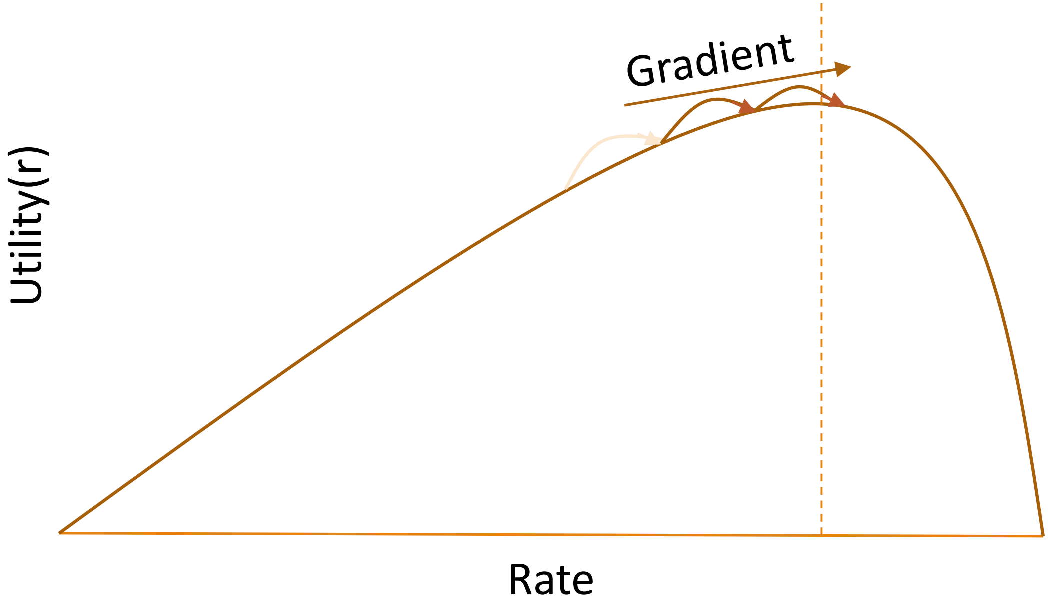




Kernel Challenge: Packet-Rate Associations

User-space: Unique packet IDs, per-packet acks

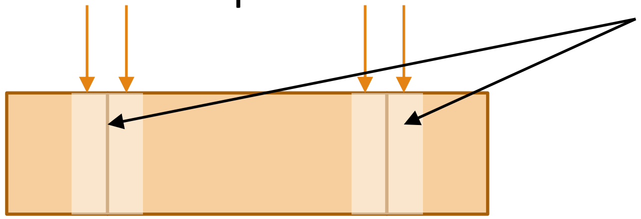
PCC-Kernel: Approximate packet-rate association

Unique packet IDs in acks

Result: Easy to know the rate at which packets were sent

Acks aggregated, packets do not have unique IDs

Uncertainty bound, at most 20% of packets



Result: Hard to know which interval a packet was sent in, so rate may not be known.

Why not `rate_samples`?

Introduced with BBR

```
struct rate_sample {
	u64  prior_mstamp; /* starting timestamp for interval */
	u32  prior_delivered;	/* tp->delivered at "prior_mstamp" */
	s32  delivered;		/* number of packets delivered over interval */
	long interval_us;	/* time for tp->delivered to incr "delivered" */
	long rtt_us;		/* RTT of last (S)ACKed packet (or -1) */
	int  losses;		/* number of packets marked lost upon ACK */
	u32  acked_sacked;	/* number of packets newly (S)ACKed upon ACK */
	u32  prior_in_flight;	/* in flight before this ACK */
	bool is_app_limited;	/* is sample from packet with bubble in pipe? */
	bool is_retrans;	/* is sample from retransmission? */
	bool is_ack_delayed;	/* is this (likely) a delayed ACK? */
};
```

Why not `rate_samples`?

The data overlaps

- a single packet's result appears in multiple samples

Cannot configure timing

- Short samples would make it easier to group them into intervals
- Configurable-length samples could be used directly.

Additional information/configuration could make them more general:

- Includes no data about pacing rate (some algorithm's actions)
- Lost and delivered packets may not be from the same timeframe (loss can be learned about later)

Kernel Challenge: Dealing with Approximations

The PCC kernel implementation makes more approximations:

- Packet-interval association
- Calculating the change in latency

Result: Unstable gradients

Set minimum rate change to 2%

Performance Results

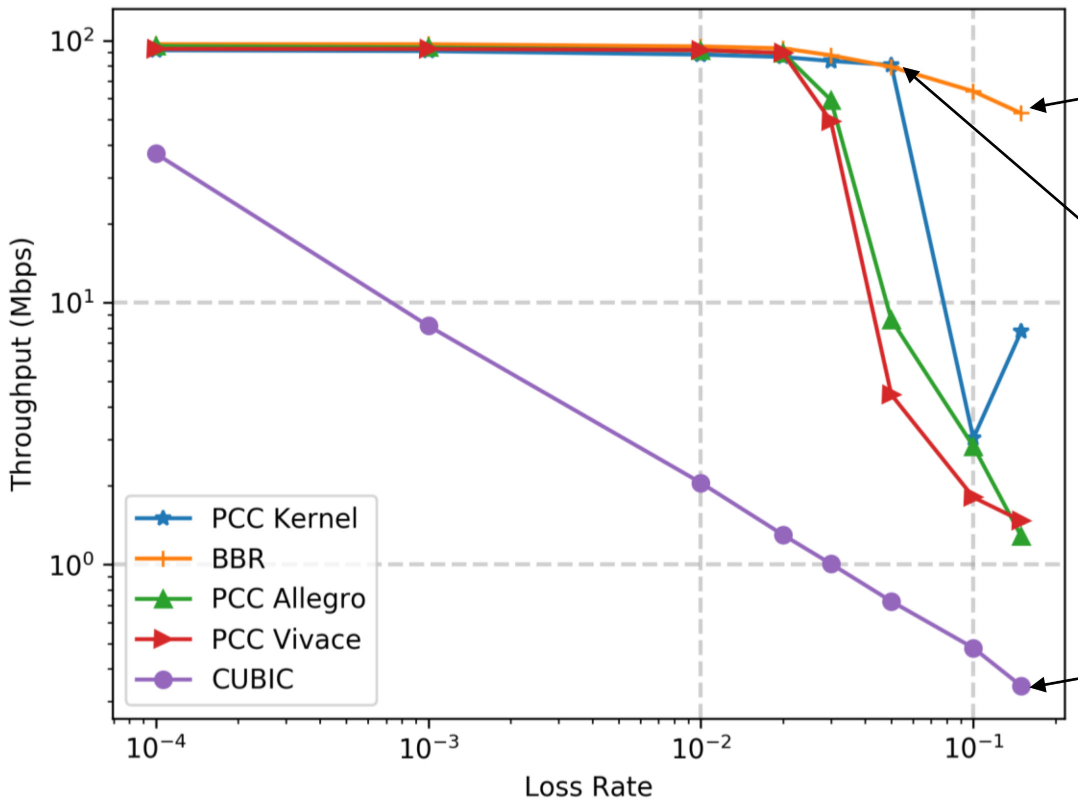
Preliminary results from Pantheon

- Loss Resilience
- Buffer Bloat
- Loss at Convergence

Compared against:

- The userspace versions of Allegro and Vivace
- CUBIC
- BBR

High Loss Resilience



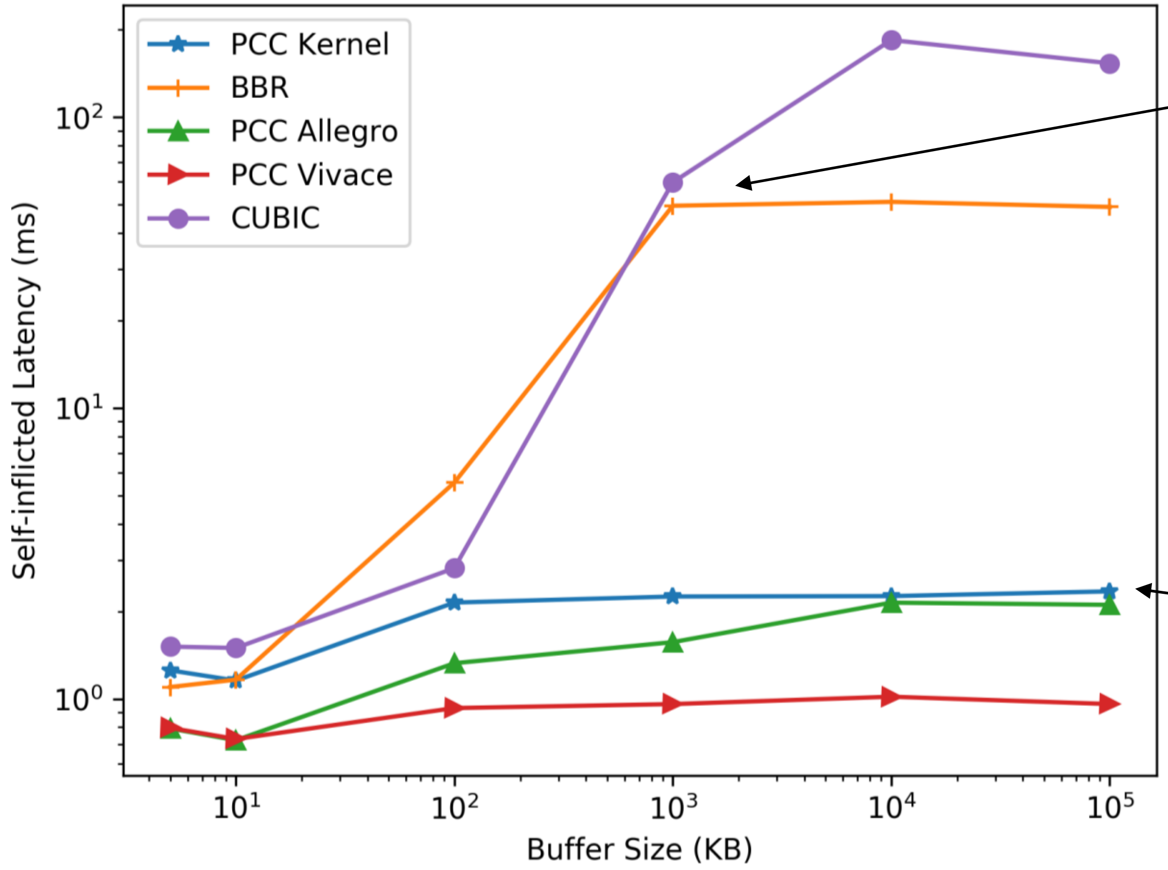
BBR is resilient up to 10% loss and continues to perform well at 15% loss

PCC-Kernel is resilient up to 5% loss

It’s CUBIC, what did you expect?

100Mbps, 30ms rtt, 750KB buffer

Low Buffer Bloat

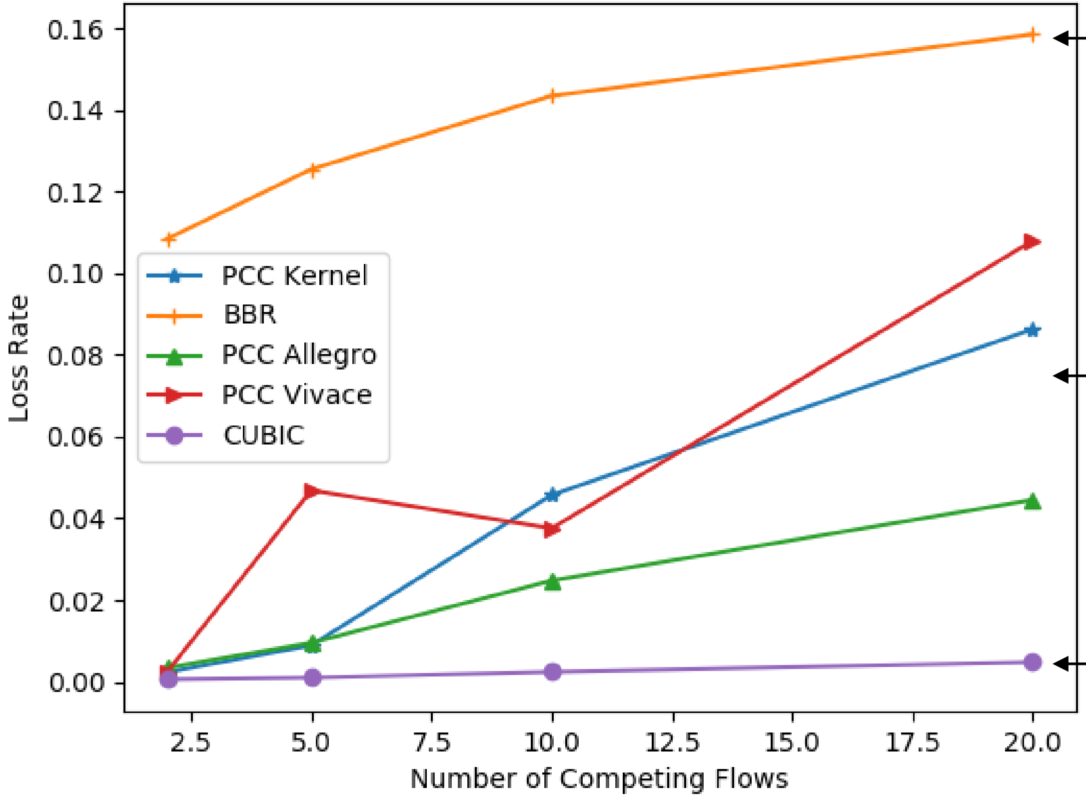


BBR and CUBIC both fill buffers up to 1000KB.

The PCC variants have about 1ms of self-inflicted latency

100Mbps, 30ms rtt, 0% random loss

Loss at Convergence



BBR converges to about 15% loss rate.

For 10 or fewer flows, PCC variants have less than 5% loss rate, but they grow to about 10%.

TCP maintains very low loss rate for many flows.

100Mbps, 30ms rtt, 750KB buffer

Conclusion

Promising initial results

We aren't done yet:

- Still in early stages
- Improving sampling in the kernel
- Exposing utility function parameters to the application

Code is available on Github: https://github.com/PCCproject/PCC-Kernel

For more detailed information on PCC: http://www.pccproject.net