

Extending SDN to the Data Plane

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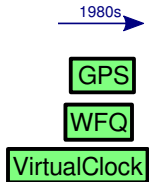
<http://web.mit.edu/anirudh/www/sdn-data-plane.html>

Switch Data Planes today

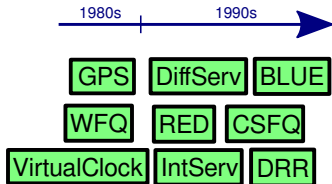
Two key decisions on a per-packet basis:

- ▶ **Scheduling:** Which packet to transmit next?
- ▶ **Queue Management:** How long can queues grow? Which packet to drop?

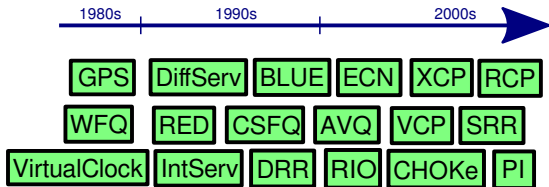
The long lineage of in-network algorithms



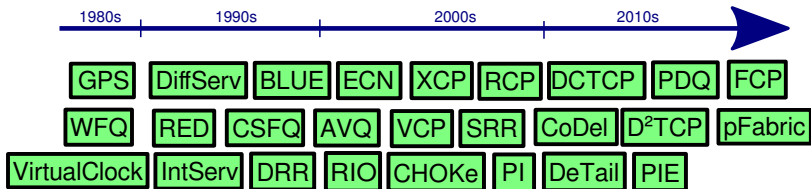
The long lineage of in-network algorithms



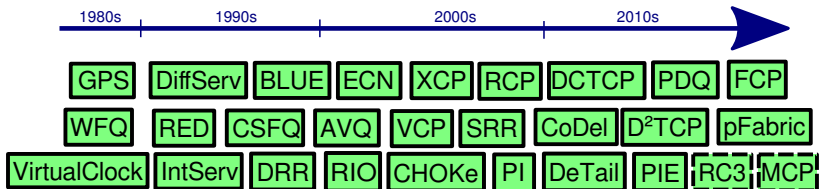
The long lineage of in-network algorithms



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The long lineage of in-network algorithms



The Data Plane is continuously evolving

- ▶ Each scheme wins in its own evaluation.
- ▶ Quest for a “silver bullet” in-network method.

We disagree: There is no silver bullet!

- ▶ Different applications care about different objectives.
- ▶ Applications use different transport protocols.
- ▶ Networks are heterogeneous.

Our work:

- ▶ Quantify non-universality of in-network methods.
- ▶ Extend SDN to the Data Plane to handle in-network diversity.

Quantifying “No Silver Bullet”: Network Configurations

<u>Configuration</u>	<u>Description</u>
CoDel+FCFS	One shared FCFS queue with CoDel
CoDel+FQ	Per-flow fair queueing with CoDel on each queue (Nichols 2013)
Bufferbloat+FQ	Per-flow fair queueing with deep buffers on each queue

Quantifying “No Silver Bullet”: Workloads and Objectives

<u>Workload</u>	<u>Description</u>	<u>Objective</u>
Bulk	Long-running bulk transfer flow	Max. throughput
Web	Switched flow with ON/OFF periods	Min. 99.9 %ile flow completion time
Interactive	Long-running interactive flow	Max. $\frac{\text{throughput}}{\text{delay}}$

Quantifying “No Silver Bullet”

CoDel+FCFS

CoDel+FQ

Bufferbloat+FQ

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CoDel+FCFS

Experiment configuration:
Workload: 1 Bulk flow + 1 Web Flow
Network: LTE link with 150 ms min. RTT

CoDel+FQ

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Bulk Tpt: 3.9 Mbps

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Web Tail FCT: 43 s

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Bulk Tpt: 11.2 Mbps

Bufferbloat+FQ

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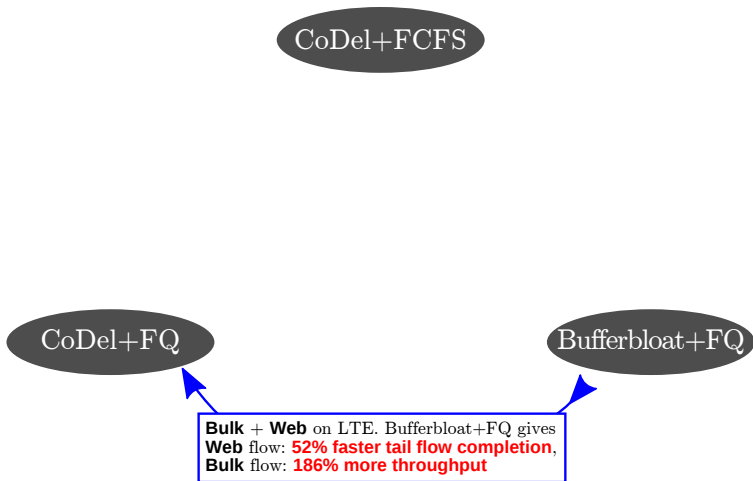
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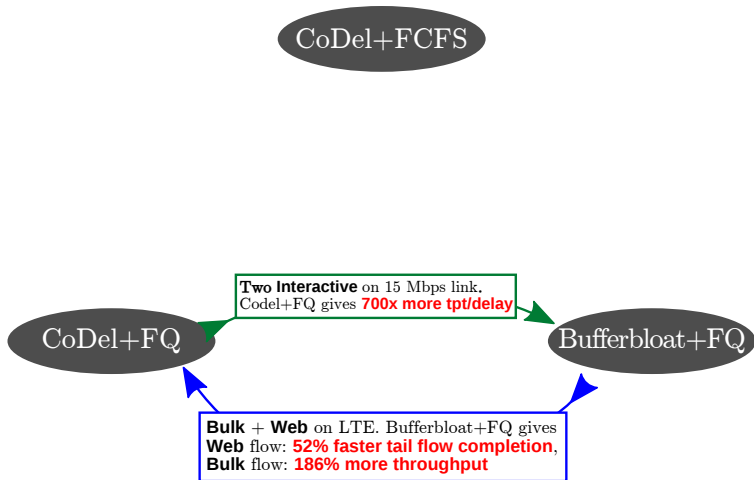
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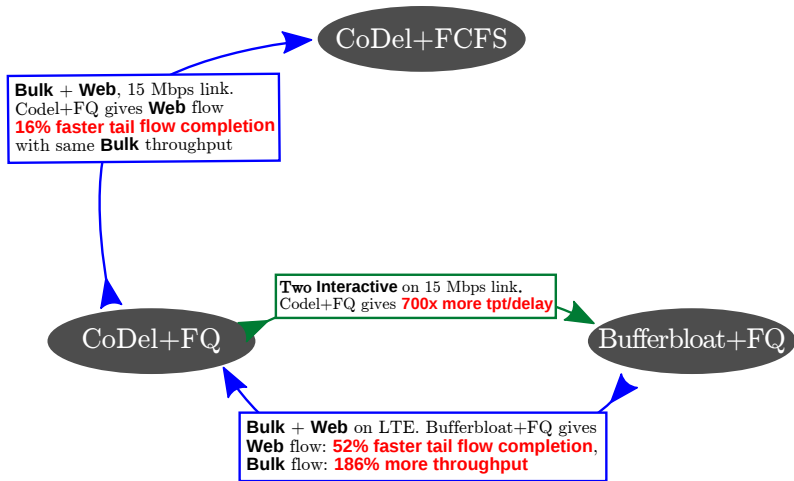
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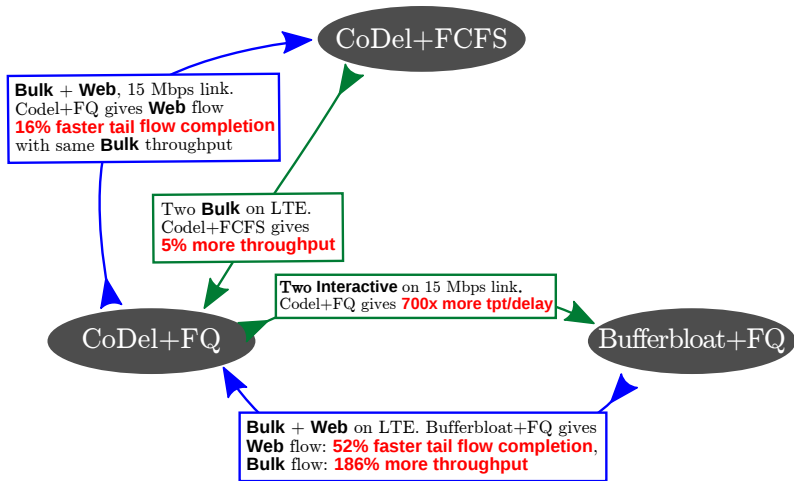
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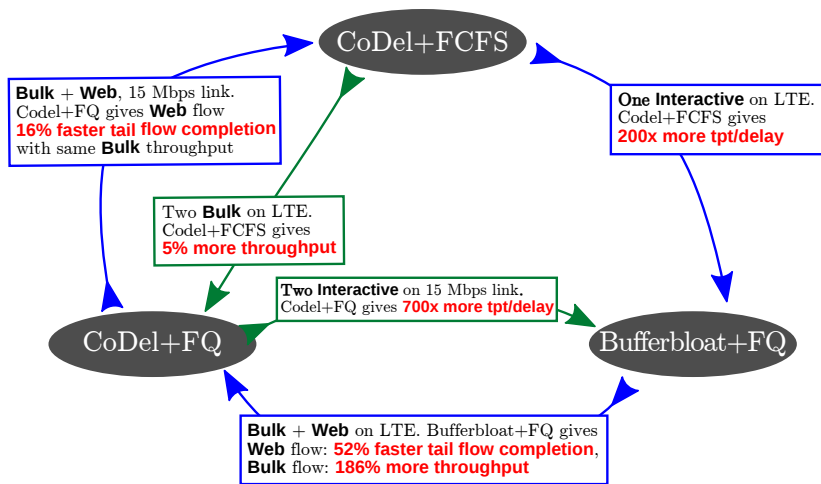
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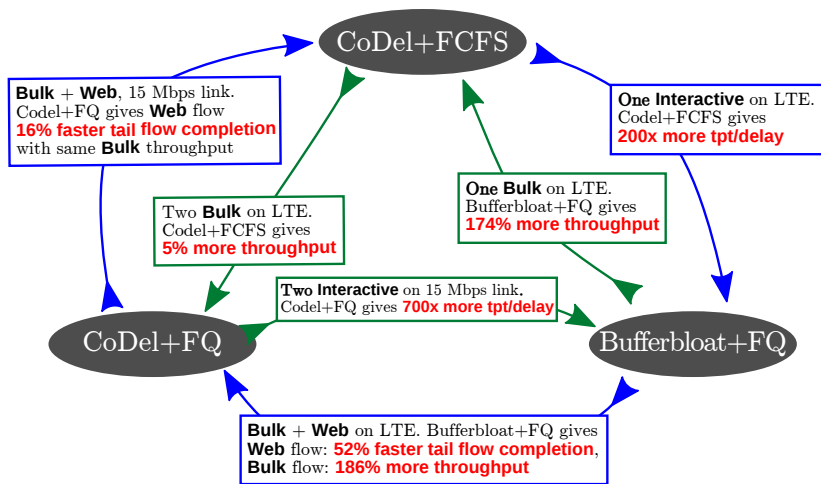
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Why is no single data plane configuration the best?

- ▶ Bufferbloat gives the best throughput on variable-rate links.
- ▶ FCFS is preferable to Fair Queuing with homogenous objectives.
- ▶ Fair Queuing is preferable with heterogeneous objectives.

So what should the network designer do?

- ▶ Don't strive for the best in-network behaviour.
- ▶ Instead, architect for evolvability.
- ▶ Conceptually, extend SDN to include the data plane as well.

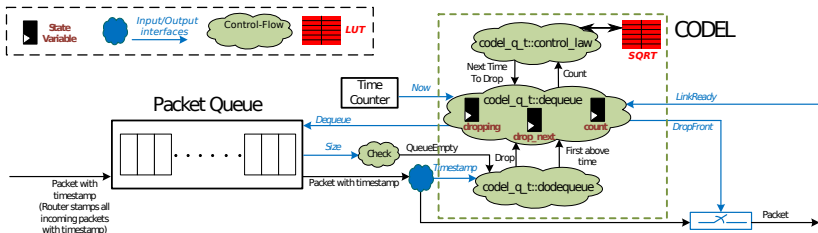
Flexibility without sacrificing performance

- ▶ Provide interfaces only to the head and tail of queues
- ▶ Operators specify only queue-management/scheduling logic
- ▶ No access to packet payloads.

Building such a data plane in four parts

- ▶ Hardware gadgets
 - ▶ Random number generators (RED, BLUE)
 - ▶ Binary tree of comparators (pFabric, SRPT)
 - ▶ Look-up tables for function approximation (CoDel, RED)
- ▶ I/O interfaces
 - ▶ Drop/mark head/tail of queue
 - ▶ Interrupts for enqueue/dequeue
 - ▶ Rewrite packet fields
- ▶ State maintenance
 - ▶ Per-flow (WFQ, DRR)
 - ▶ Per-dst address (PF)
- ▶ A domain-specific instruction set
 - ▶ Expresses control flow
 - ▶ Implements new functions unavailable in hardware

Feasibility study: CoDel



Synthesis numbers on the Xilinx Kintex-7

Resource	Usage	Fraction
Slice logic	1,256	1%
Slice logic dist.	1,975	2%
IO/GTX ports	27	2%
DSP slices	0	0%
Maximum speed	12.9 million pkts/s ~10 Gbps	

- ▶ Small fraction of the FPGA's resources.
- ▶ Can be improved by pipelining or parallelizing.

Limitations and Practical Considerations:

- ▶ Cannot express several network functions that need payloads.
- ▶ Mechanism to signal application objectives.
- ▶ Feasibility at 10G on high port-density switches.
- ▶ Energy, area, and performance costs of flexibility.

Related Work

- ▶ Active Networking, e.g., ANTS
- ▶ Software Routers, e.g., Click
- ▶ Software-Defined Networking, e.g., OpenFlow

Conclusion

- ▶ No silver bullet to in-network resource allocation.
- ▶ Algorithms will evolve: the data plane should help
- ▶ Reproduce our results:
<http://web.mit.edu/anirudh/www/sdn-data-plane.html>