جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

WQM: An Aggregation-Aware Queue Management Scheme for IEEE 802.11n Based Networks

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Users Do Respond to Latency

Google

500 ms of latency leads to 20% drop in traffic

What Google knows (Marissa Mayer)

amazon

100 ms delay costs 1% of sales

Make Data Useful (Greg Linden)

YAHOO!

400 ms slowdown results in 5-9% drop in traffic

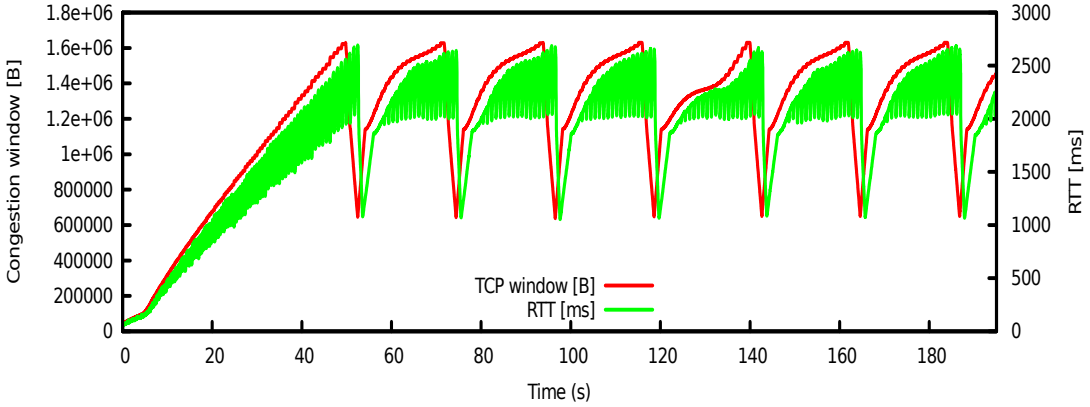
Yslow 2.0 (Stoyan Stefanov)

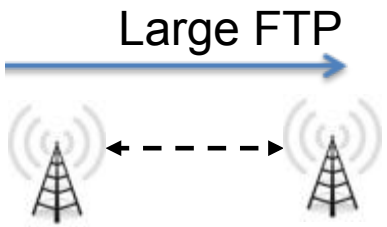
Firefox

2.2 s delay reduction increases downloads by 15.4%

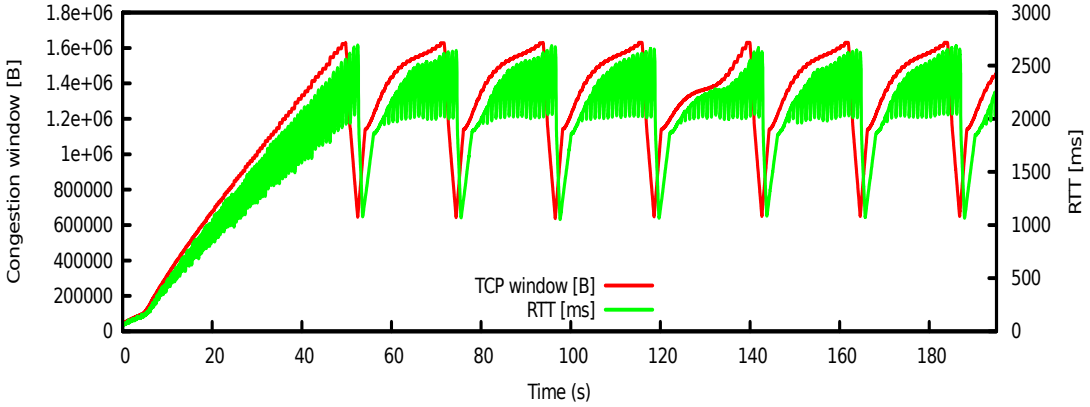
Firefox & page load speed (Blake Cutler)

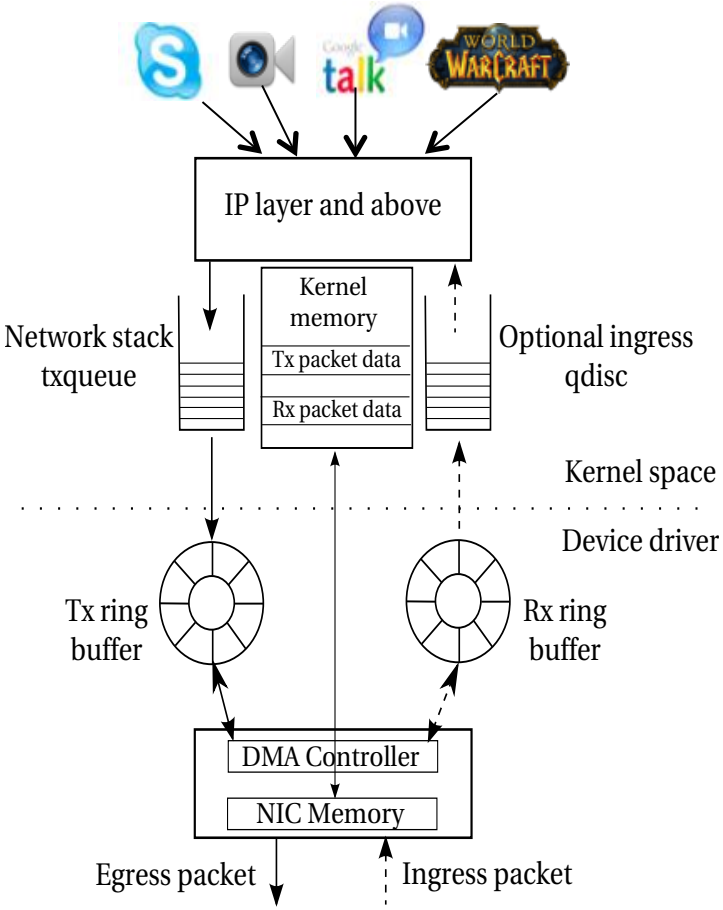
How Bad is This Latency?





What Causes Latency?





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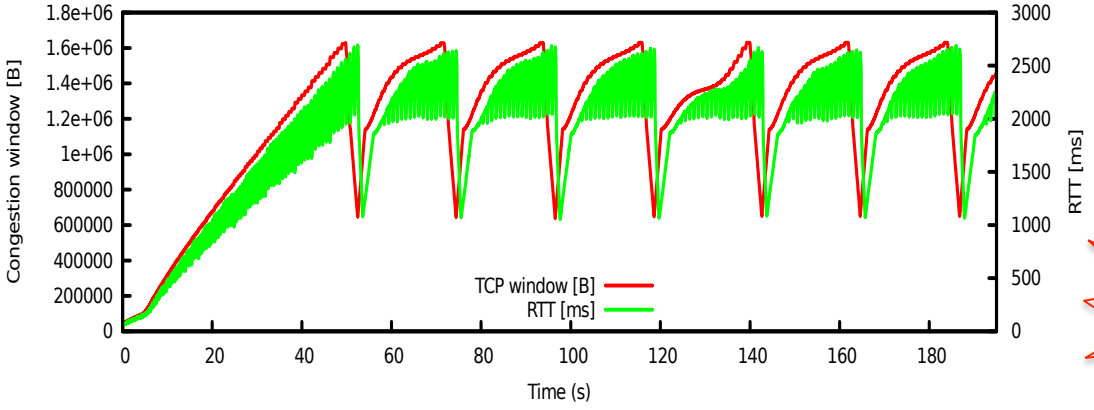

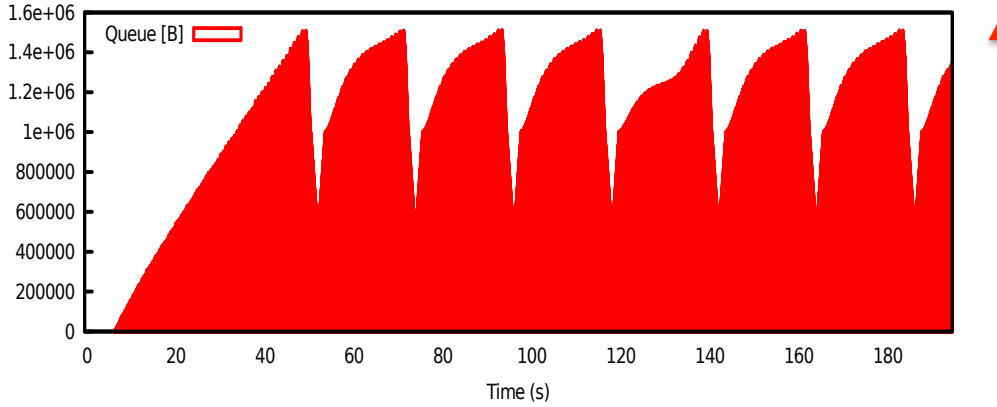

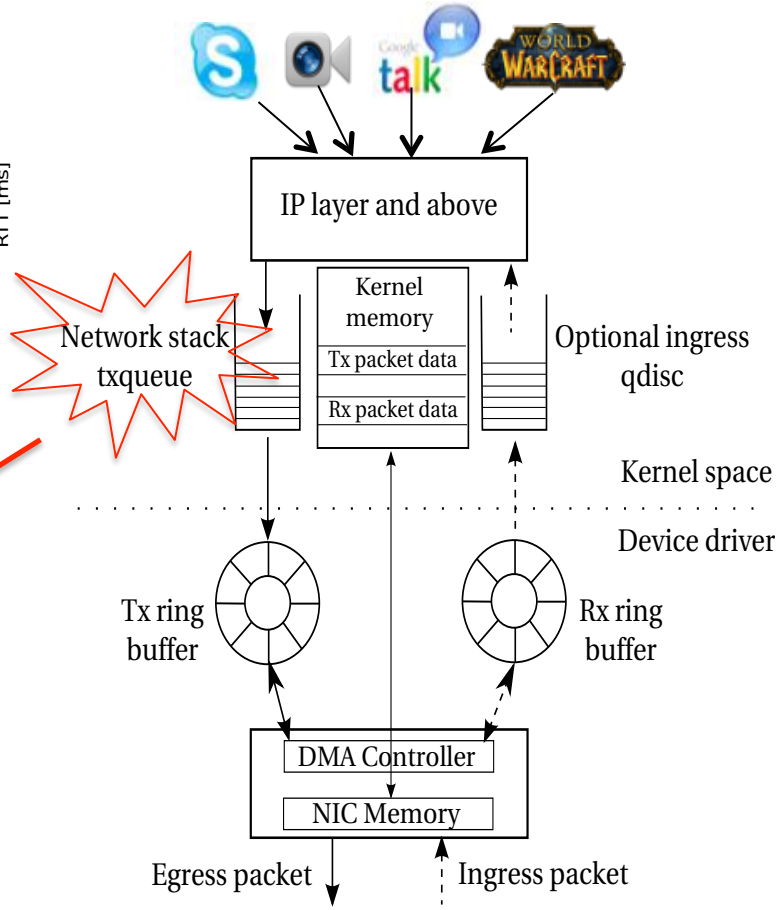

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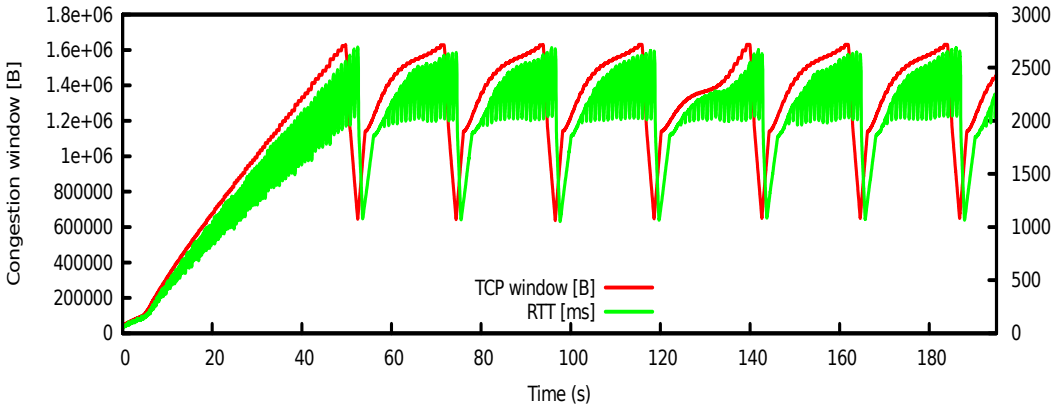
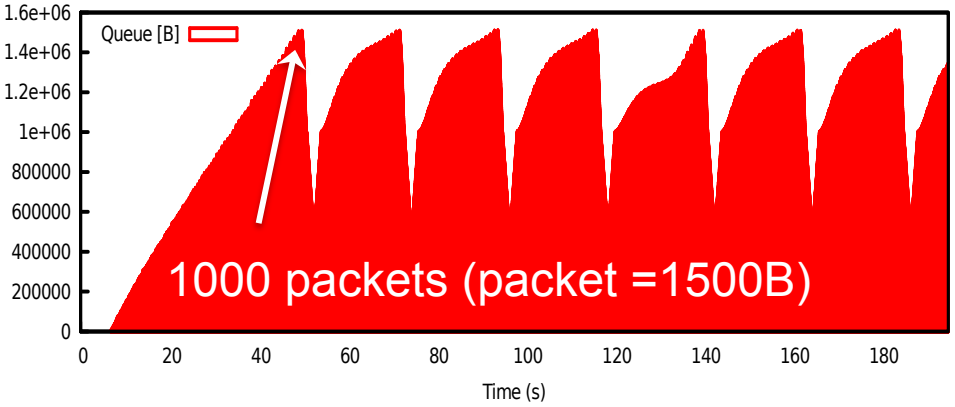
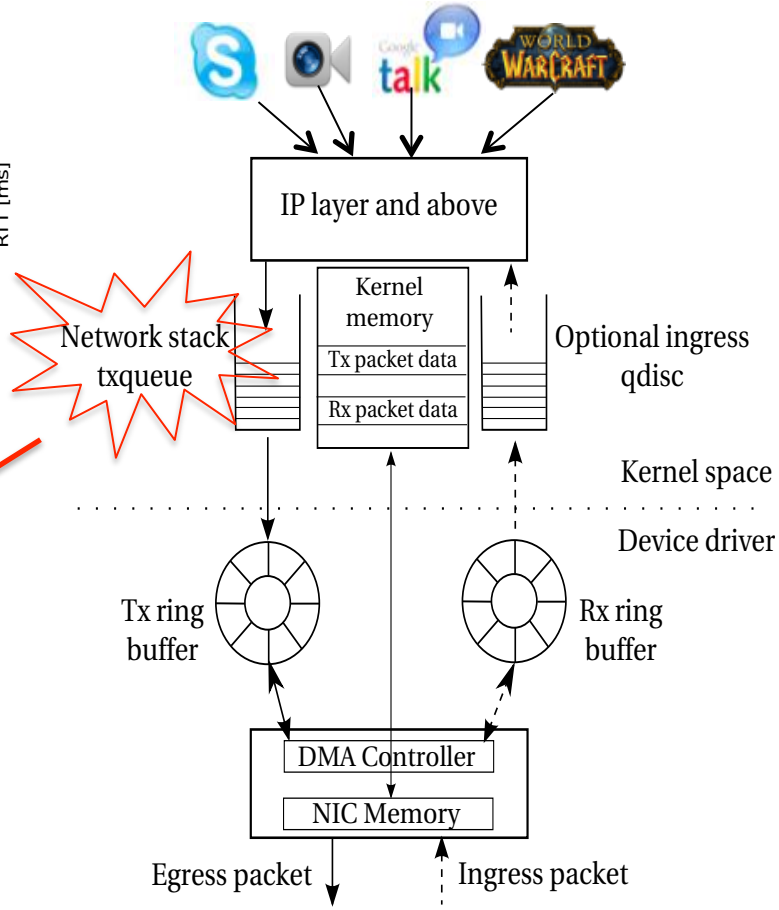
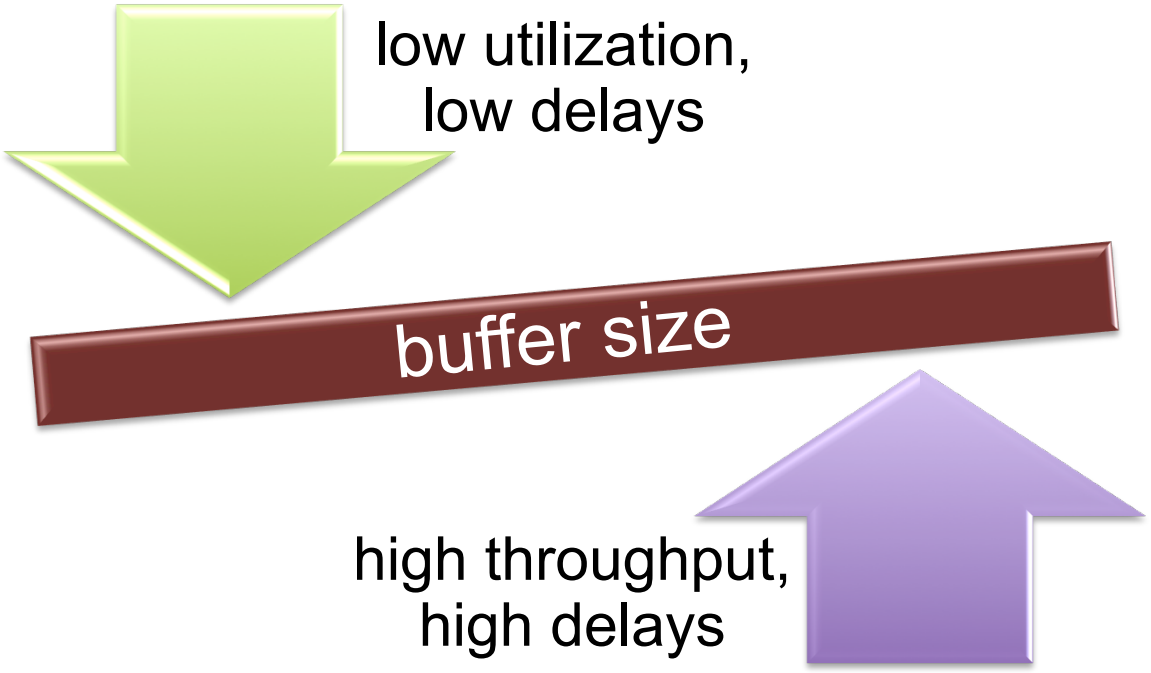






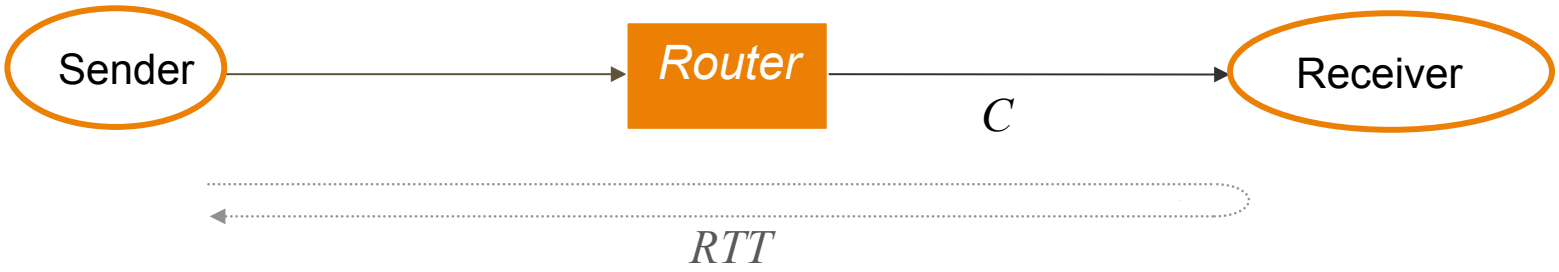
TXQUEUE BUFFERS ARE BLOATED

Problem Statement



Determine buffer size to balance throughput and delay tradeoff

Buffer Sizing Rule of Thumb

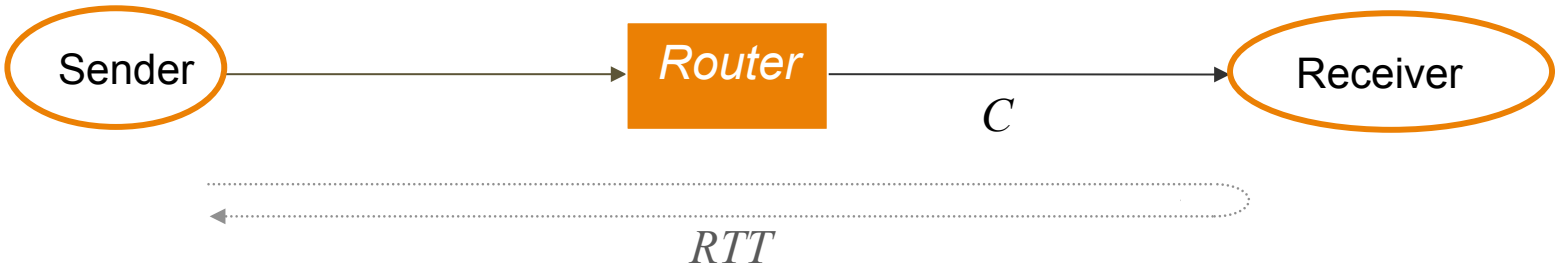


Router needs a buffer size of

$$B = RTT \times C$$

- *RTT* is the two-way propagation delay
- *C* is the bottleneck link capacity

What about Wireless Networks?



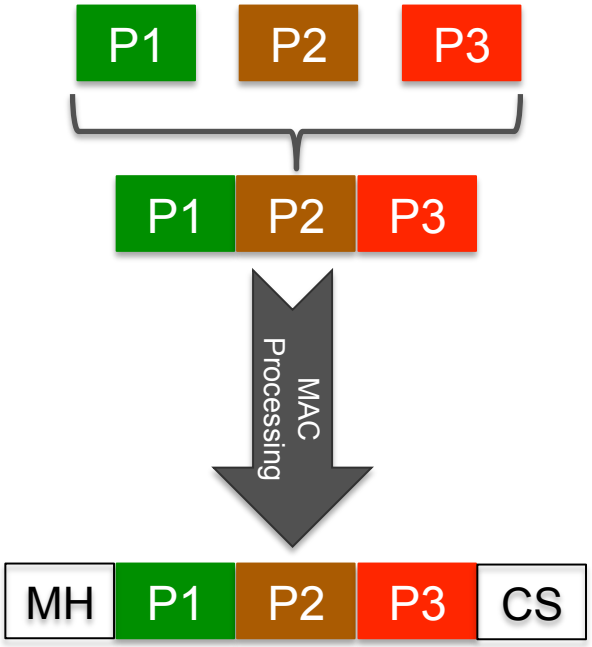
Router needs a buffer size of

$$B = RTT \times C$$

WIRELESS NETWORKS ARE DIFFERENT

Challenges in Wireless Networks

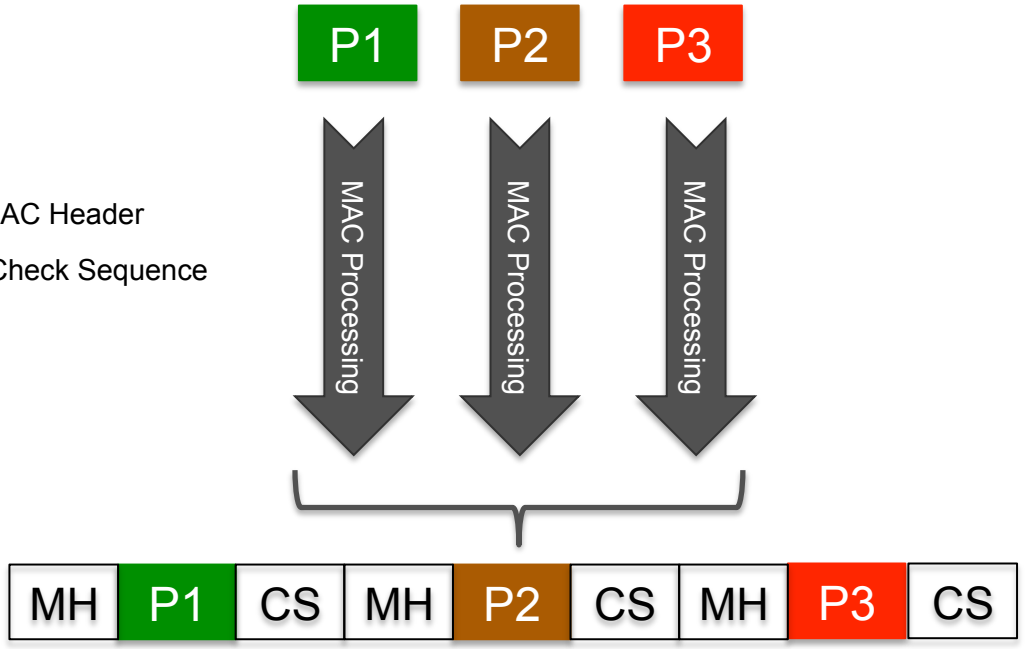
- **Frame Aggregation Scheduling**
  - Impact of large aggregates with multiple sub-frames



Aggregated MAC Service Data Unit (A-MSDU)

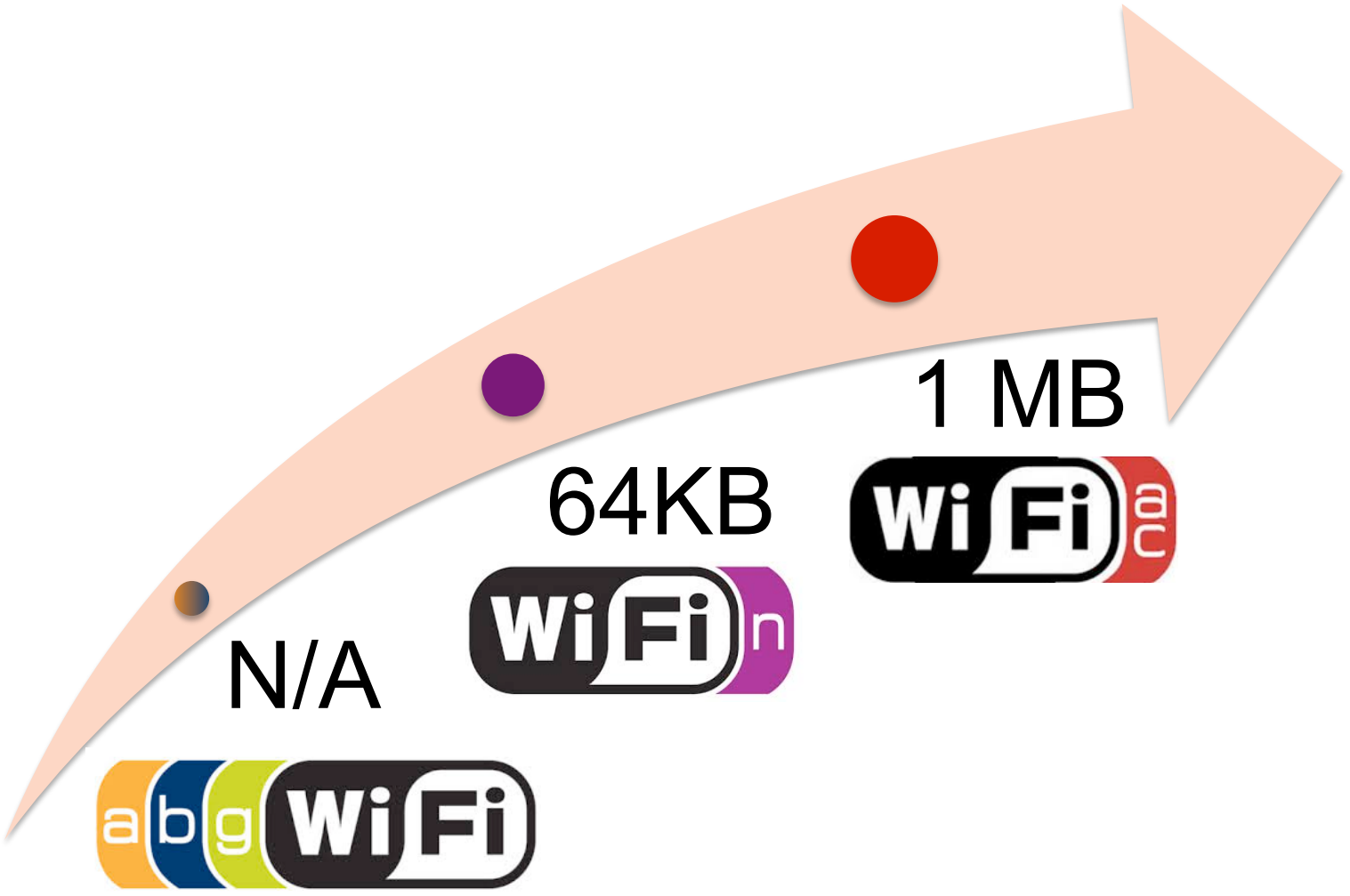
MH: MAC Header

CS: Frame Check Sequence

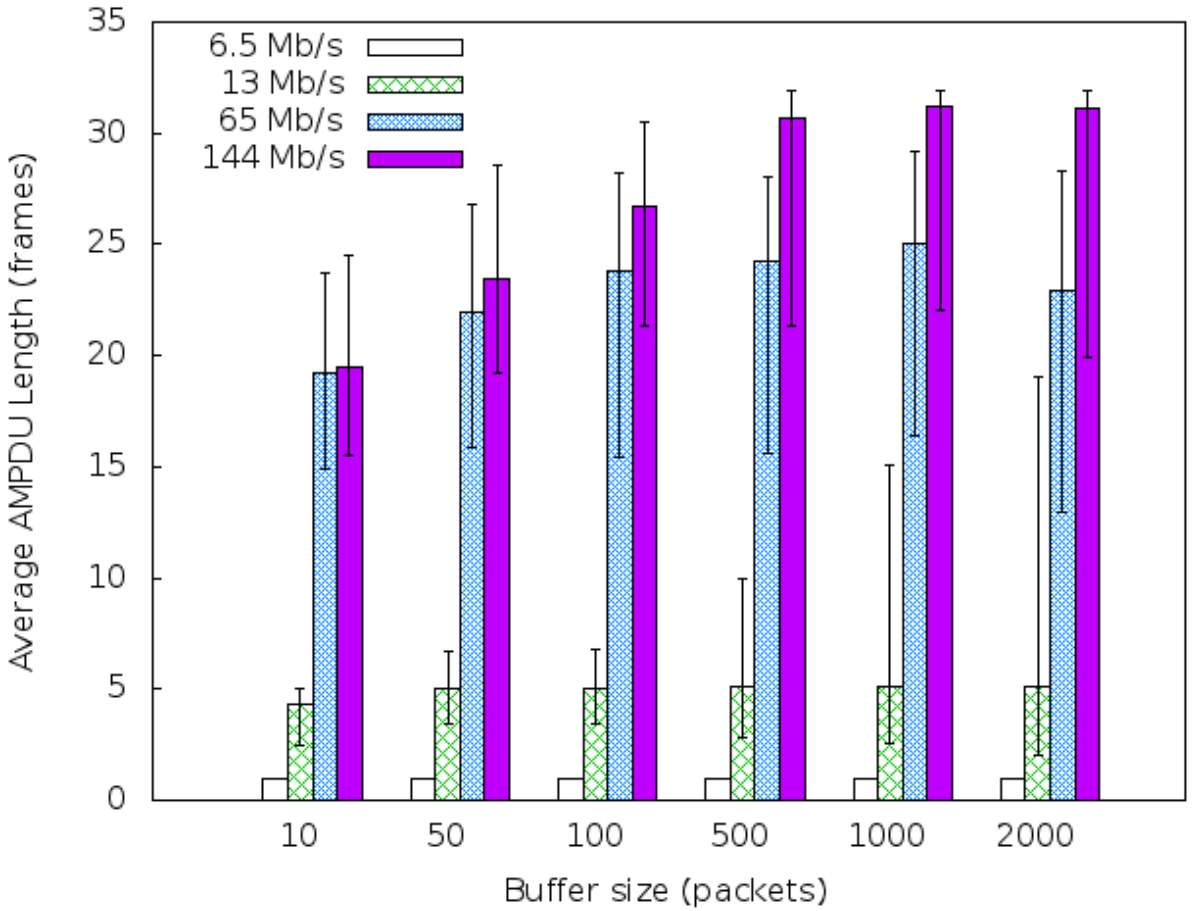


Aggregated MAC Protocol Data Unit (A-MPDU)

A-MPDU Aggregate Size

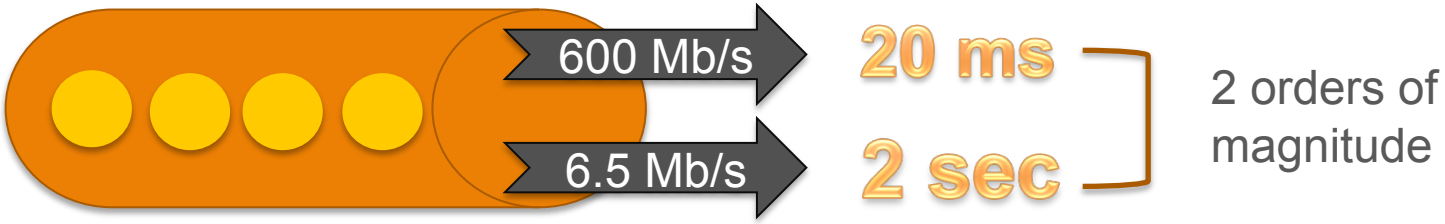


How Big is an A-MPDU?



Challenges in Wireless Networks

- **Frame Aggregation Scheduling**
  - Impact of large aggregates with multiple sub-frames
- **Variable Packet Inter-Service Rate**
  - Random MAC scheduling
  - Sporadic noise and interference
- **Adaptive link rates**
  - With the default Linux buffer size, the time to empty a full buffer:



Proposed Solution: WQM

force max-min limits on queue size

Frame Aggregation

queuing delay vs. queue size

Link Rate

account for channel busy time

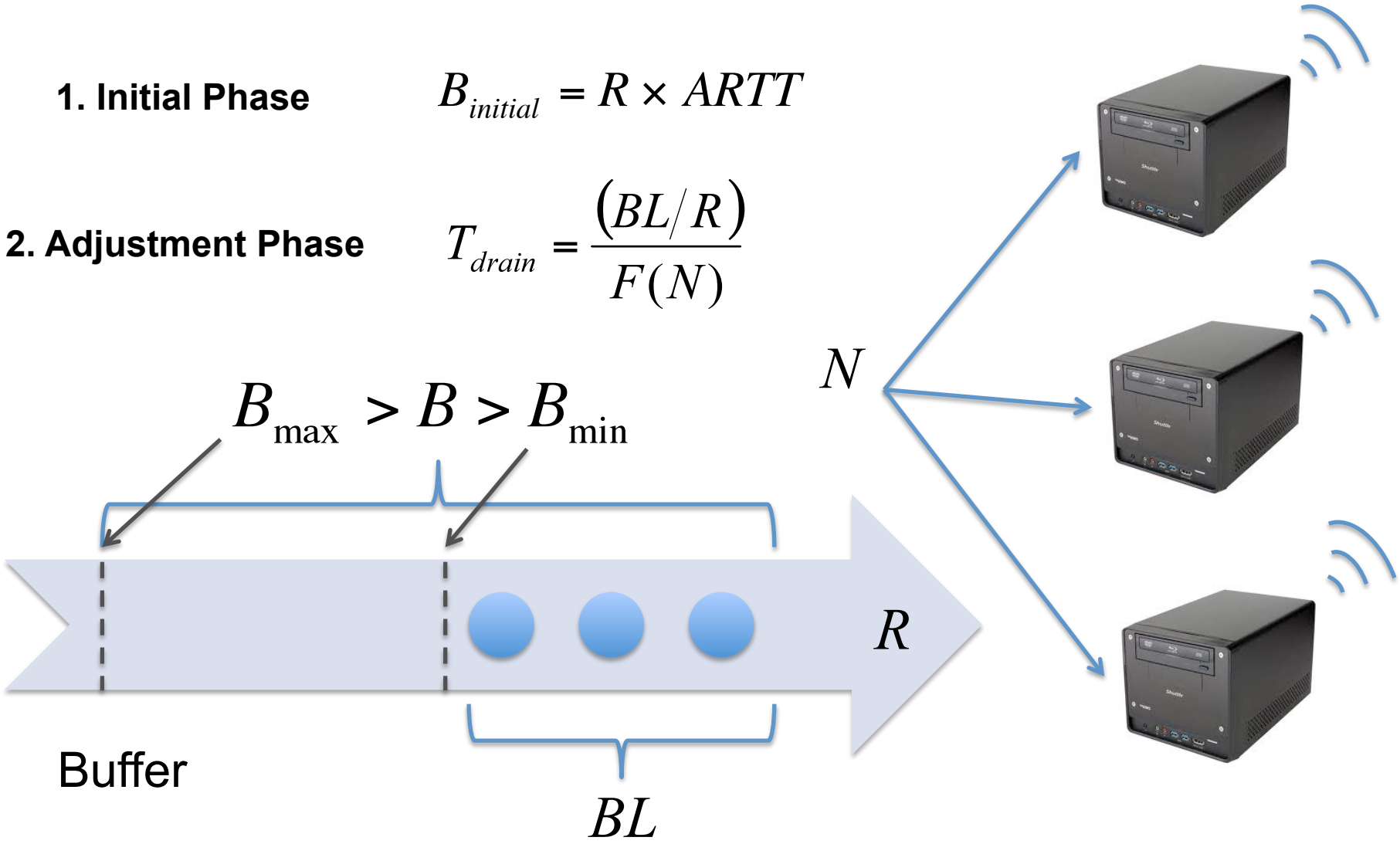
Channel Utilization

adaptively set buffer size based on network measurements

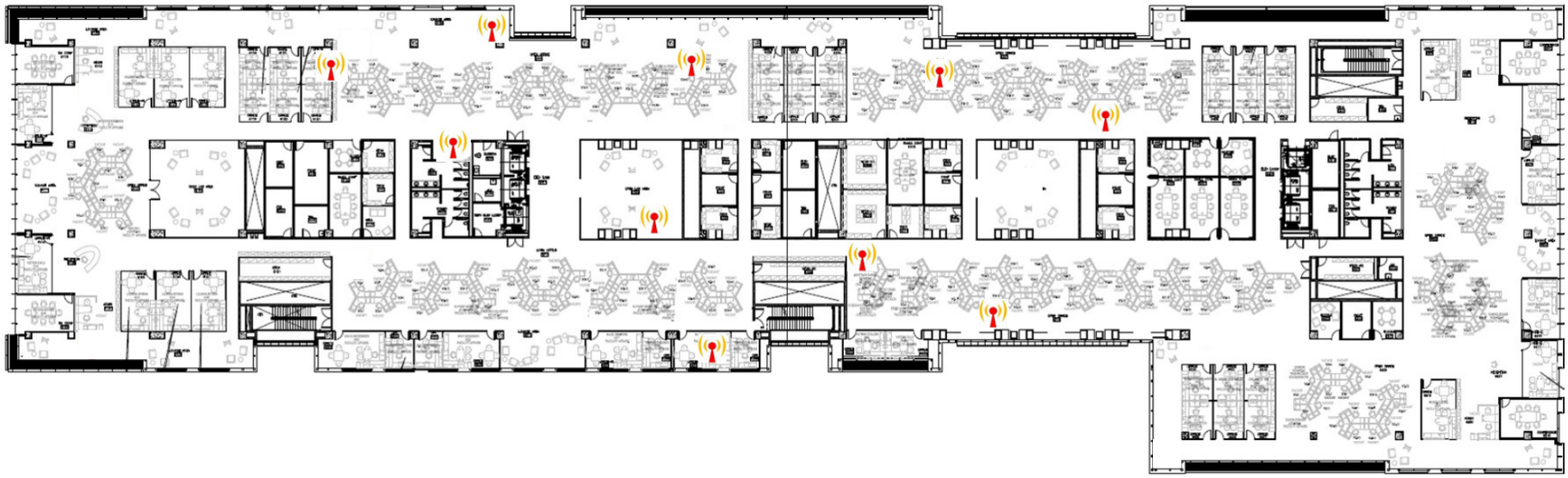
WQM Operations

1. Initial Phase $B_{initial} = R \times ARTT$

2. Adjustment Phase $T_{drain} = \frac{(BL/R)}{F(N)}$



Testbed Topology

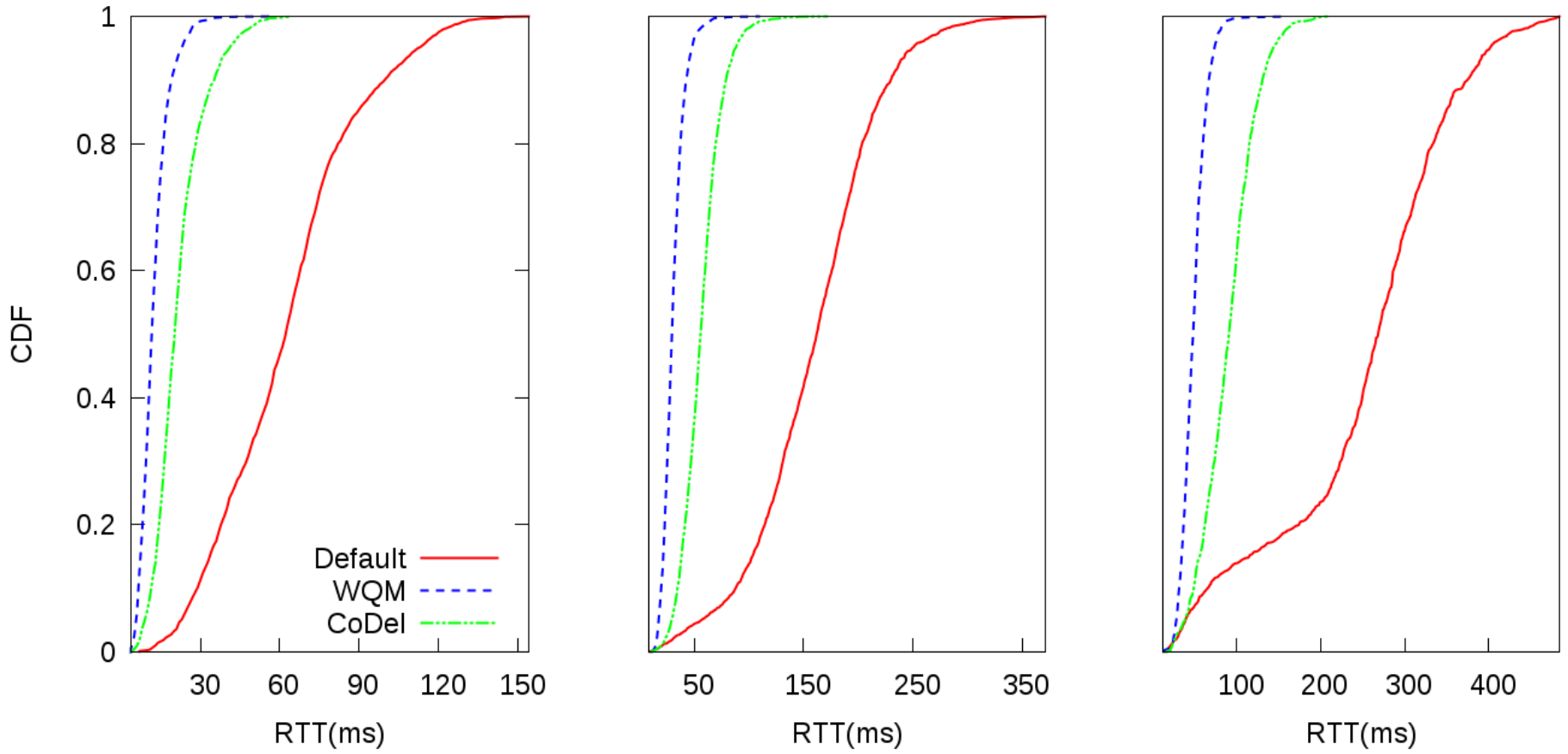


Node setup: 10 Distributed Shuttle Nodes at our campus.
Software setup: Customized Linux kernel for statistics collection
Network traffic setup: Large file transfers

Testbed Parameters

Parameter	Value
Traffic source	netperf (1.5KB packets)
Transmit queue size	1000 packets (Default size)
TCP Flavor	Cubic with window scaling
Test duration	200 seconds
Radio band	5 GHz U-NII
Spatial streams	3 MIMO streams
Linux kernel	Custom 3.9 with web10g

Single Flow Multi Hop Results

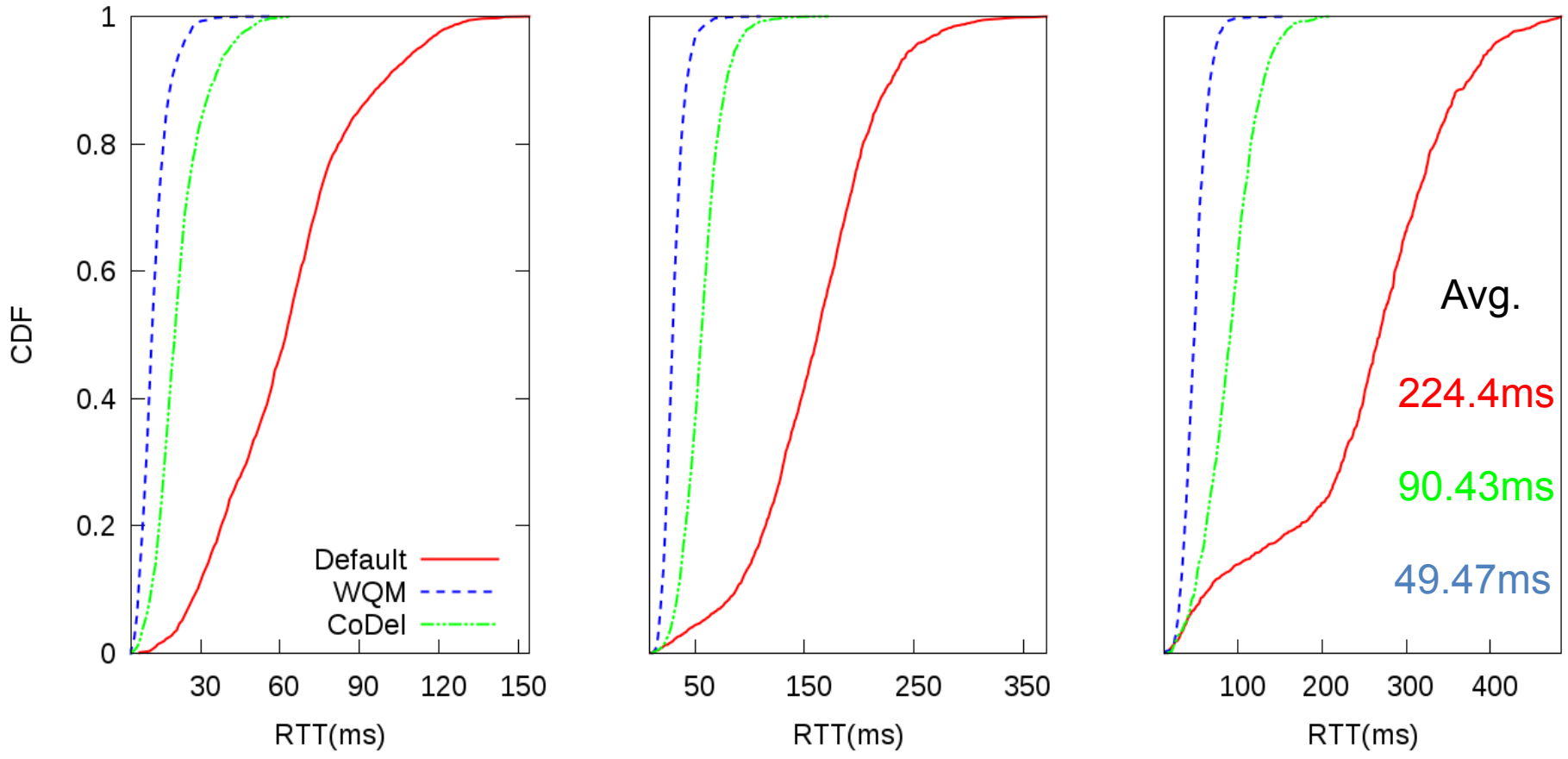


1 hop

2 hops

3 hops

Single Flow Multi Hop Results



1 hop

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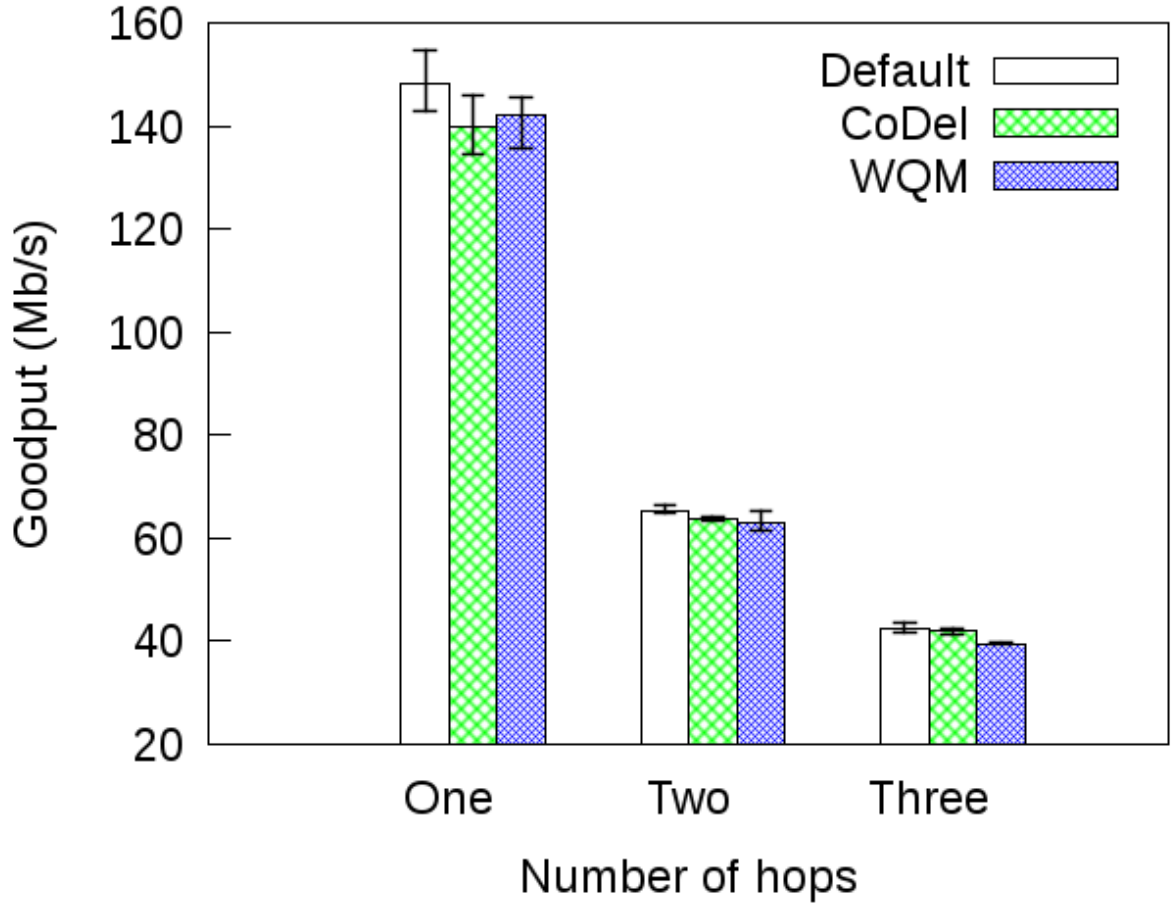
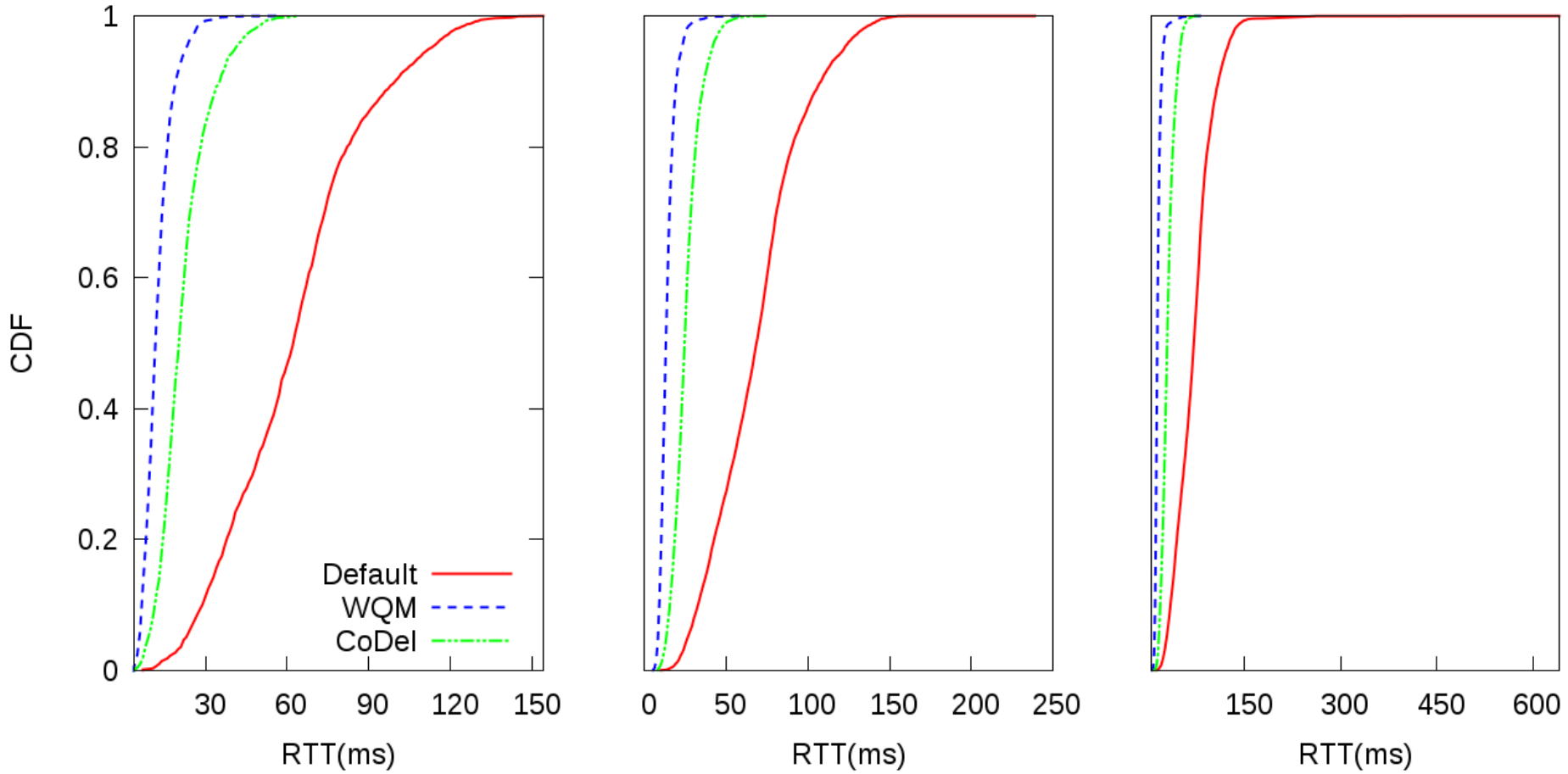
Single Flow Multi Hop Results



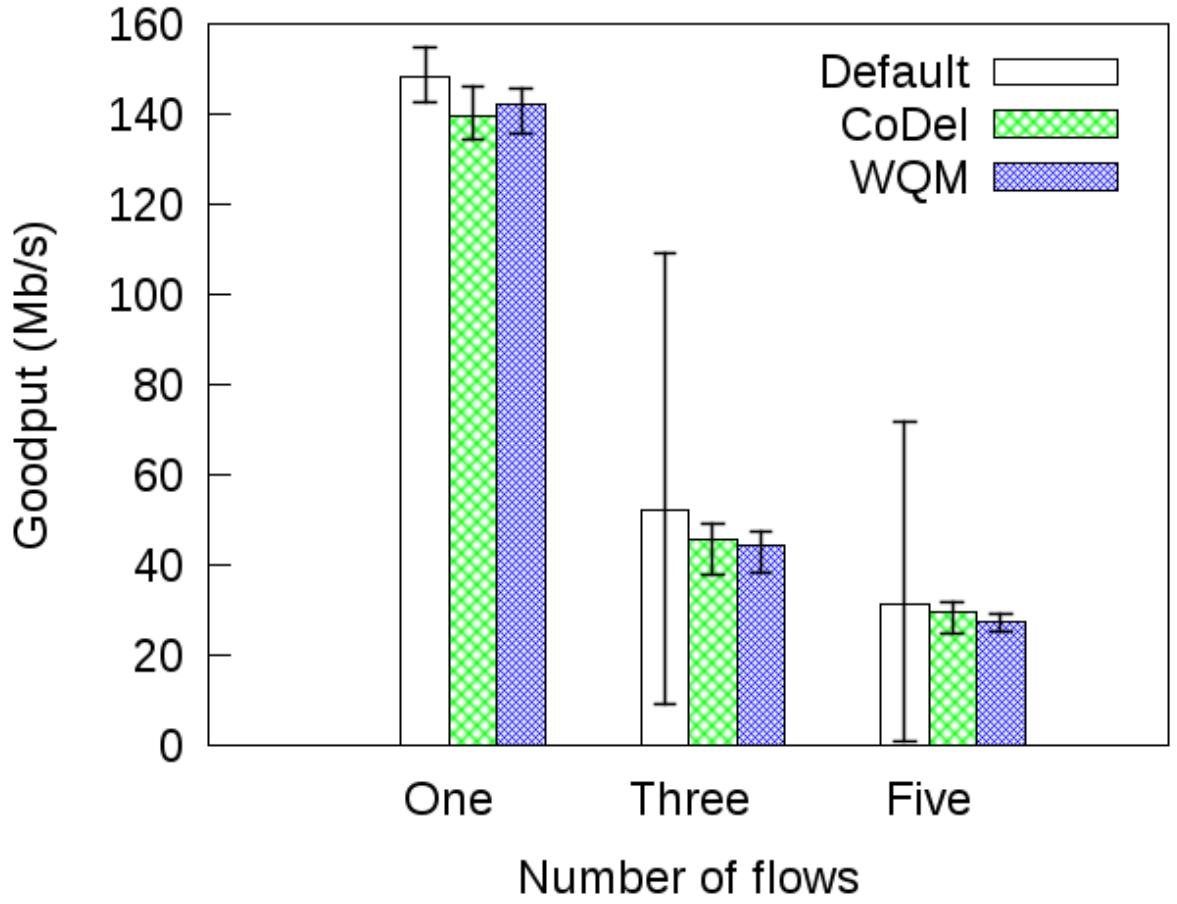
Multi Flow Single Hop Results

WQM reduces RTT by 5x compared to default buffers and 2x compared to CoDel



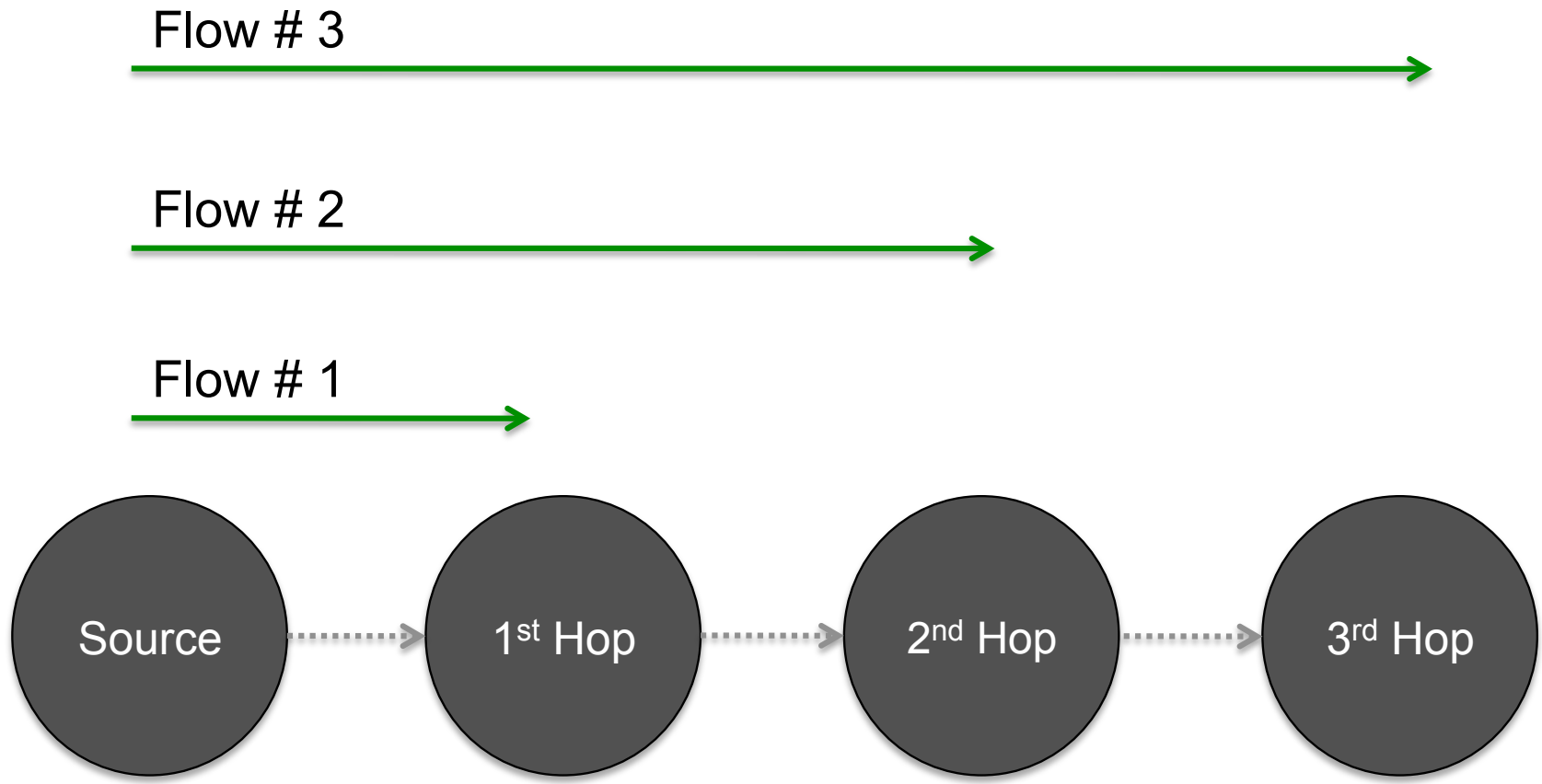
1 flow 3 flows 5 flows

Multi Flow Single Hop Results



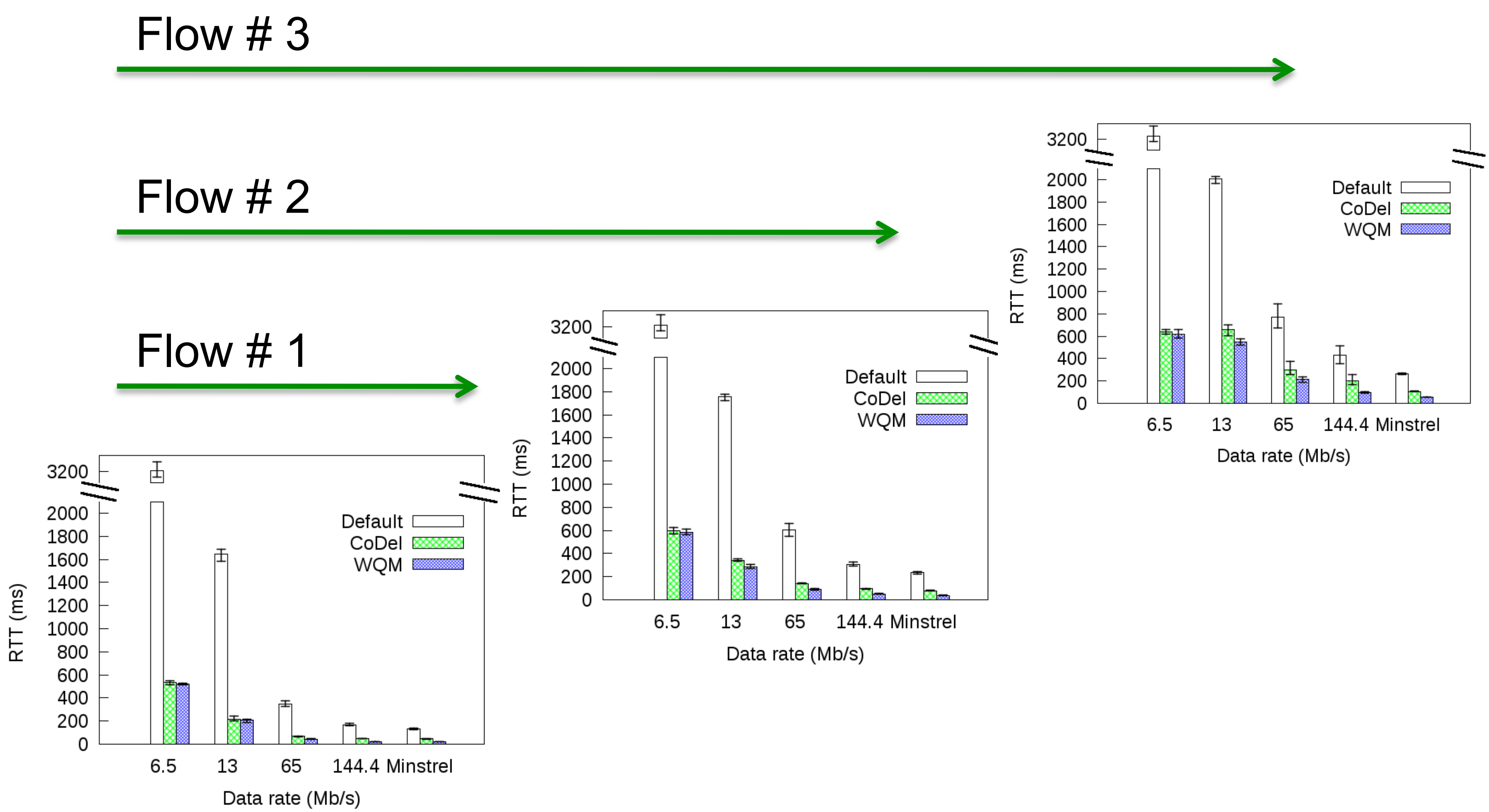
JFI for the default buffer size is 0.77 compared to 0.99 for both WQM and CoDel

Multi Flow Multi Hop Results

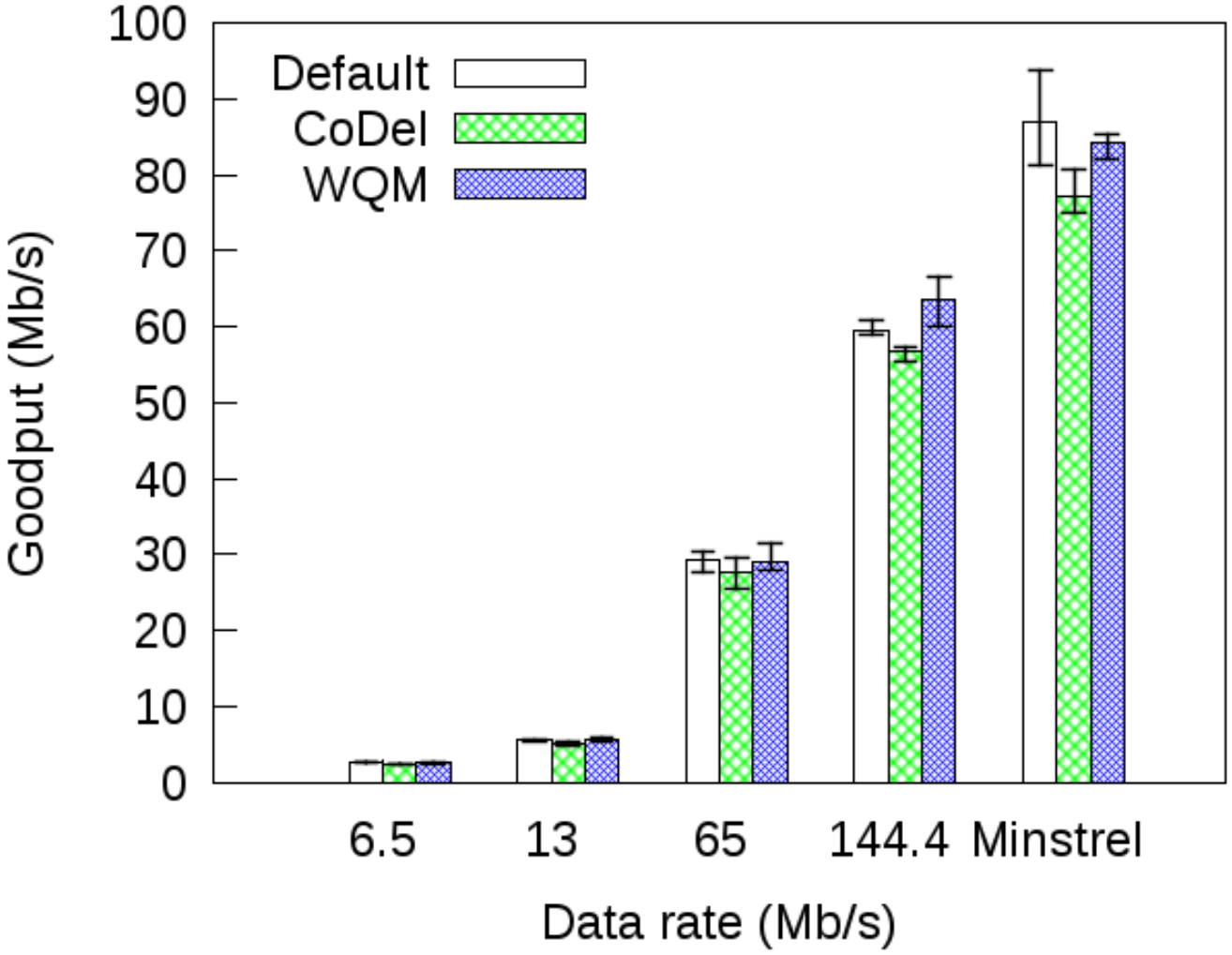


Parking Lot Topology

Multi Flow Multi Hop Results



Multi Flow Multi Hop Results



Concluding Remarks

- Choosing the optimal queue size in wireless networks is challenging
- Enhancements in 802.11n/ac requires rethink of buffer management in the wireless domain
- Solutions:
  - WQM: sizes the queue based on network load and channel conditions
- Experimental analysis shows upto 8x RTT reduction over default Linux buffers and 2x over CoDel.

Future Directions

- Study the interaction between **TCP pacing** and frame aggregation in wireless networks
- Replace WQM drop tail approach with a selective drop algorithm
- Evaluate WQM using flow separation and compare it to **FQ-CoDel**
- Compare WQM to other AQMs such as **PIE**

Questions/Comments/Feedback