Towards 10Gb/s open-source routing

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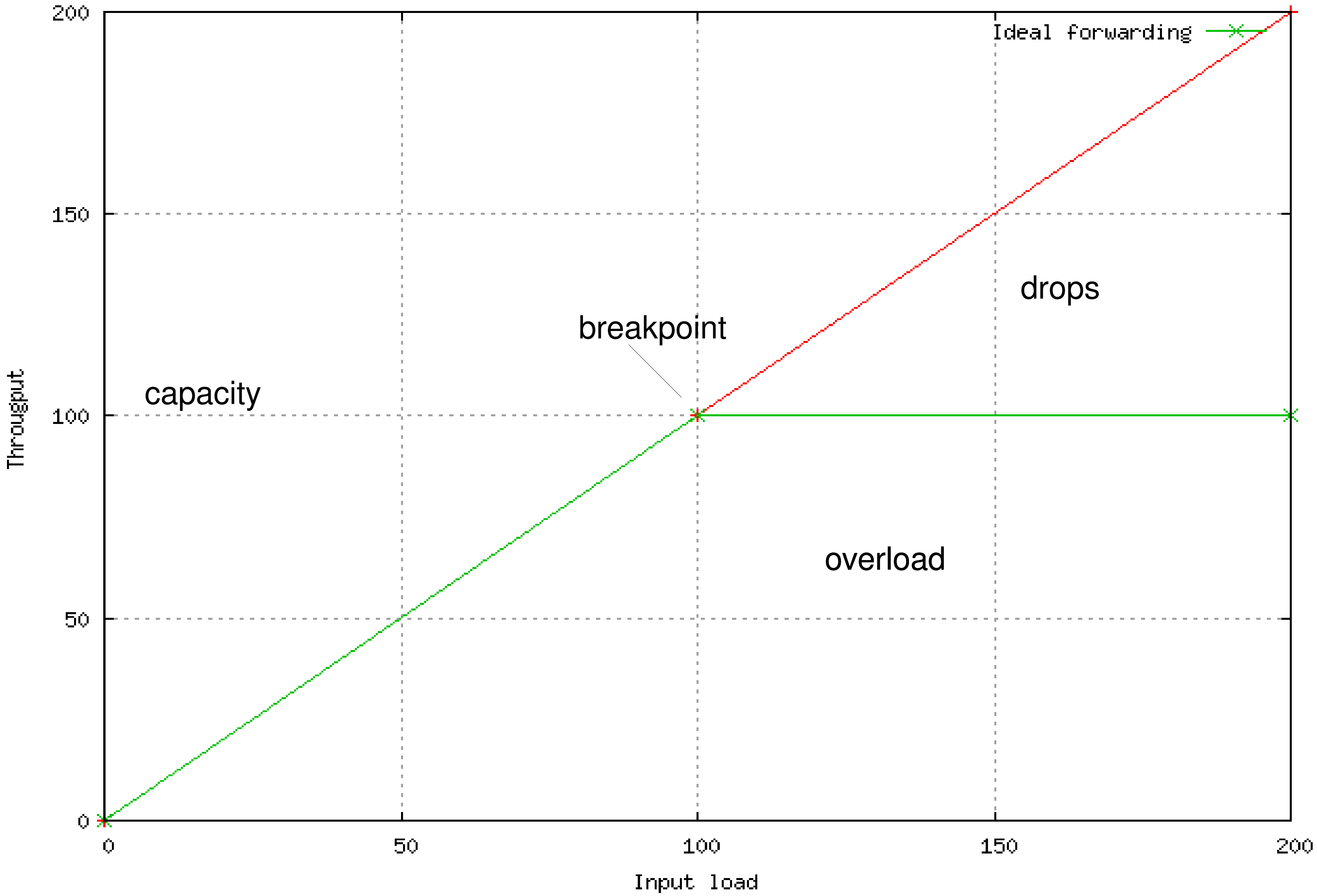
Introduction

- Investigate packet forwarding performance of new PC hardware:
  - Multi-core CPUs
  - Multiple PCI-e buses
  - 10G NICs
- Can we obtain enough performance to use open-source routing also in the 10Gb/s realm?

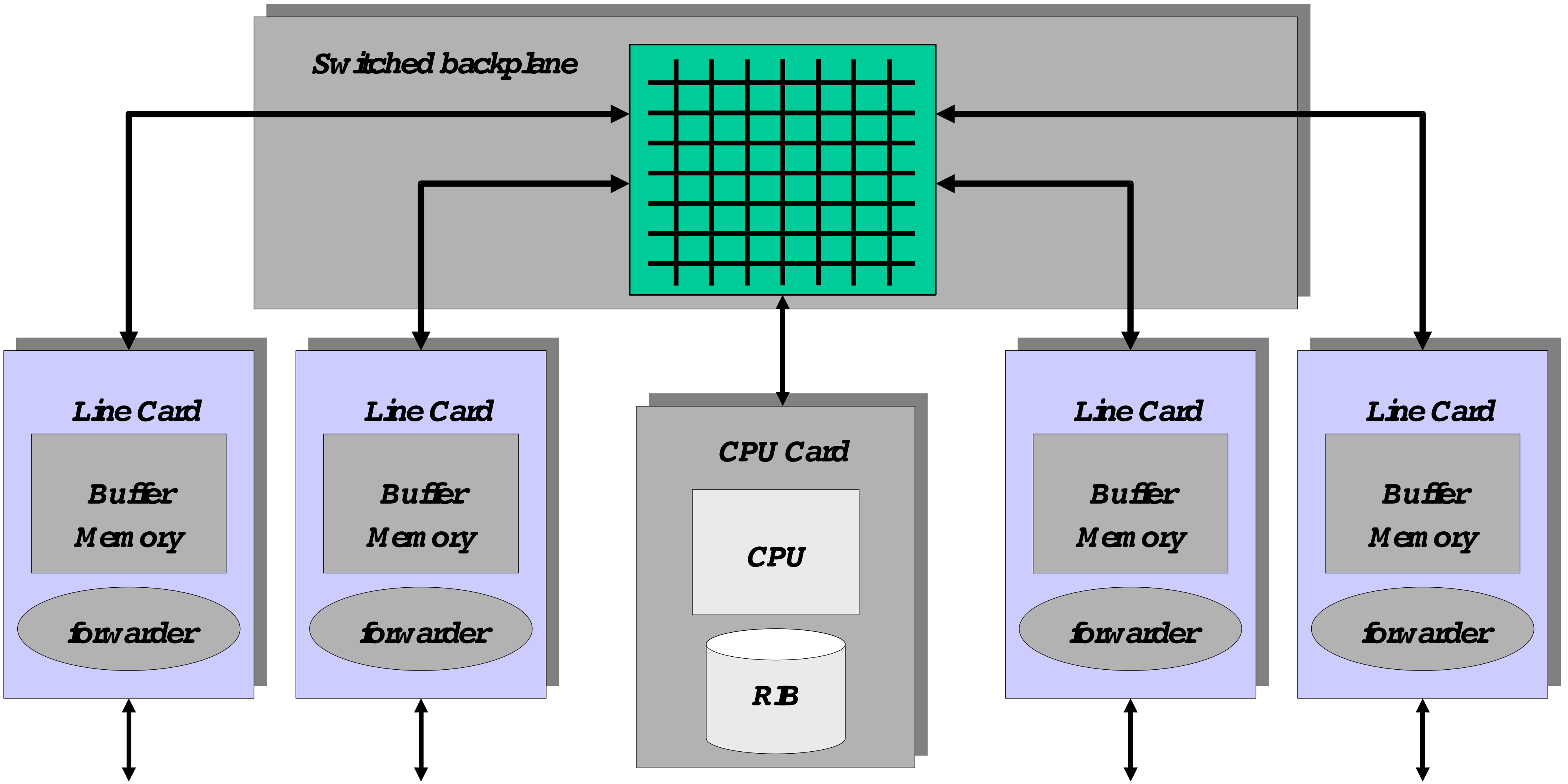
Measuring throughput

- Packet per second
  - Per-packet costs
  - CPU processing, I/O and memory latency, clock frequency
- Bandwidth
  - Per-byte costs
  - Bandwidth limitations of bus and memory

Measuring throughput

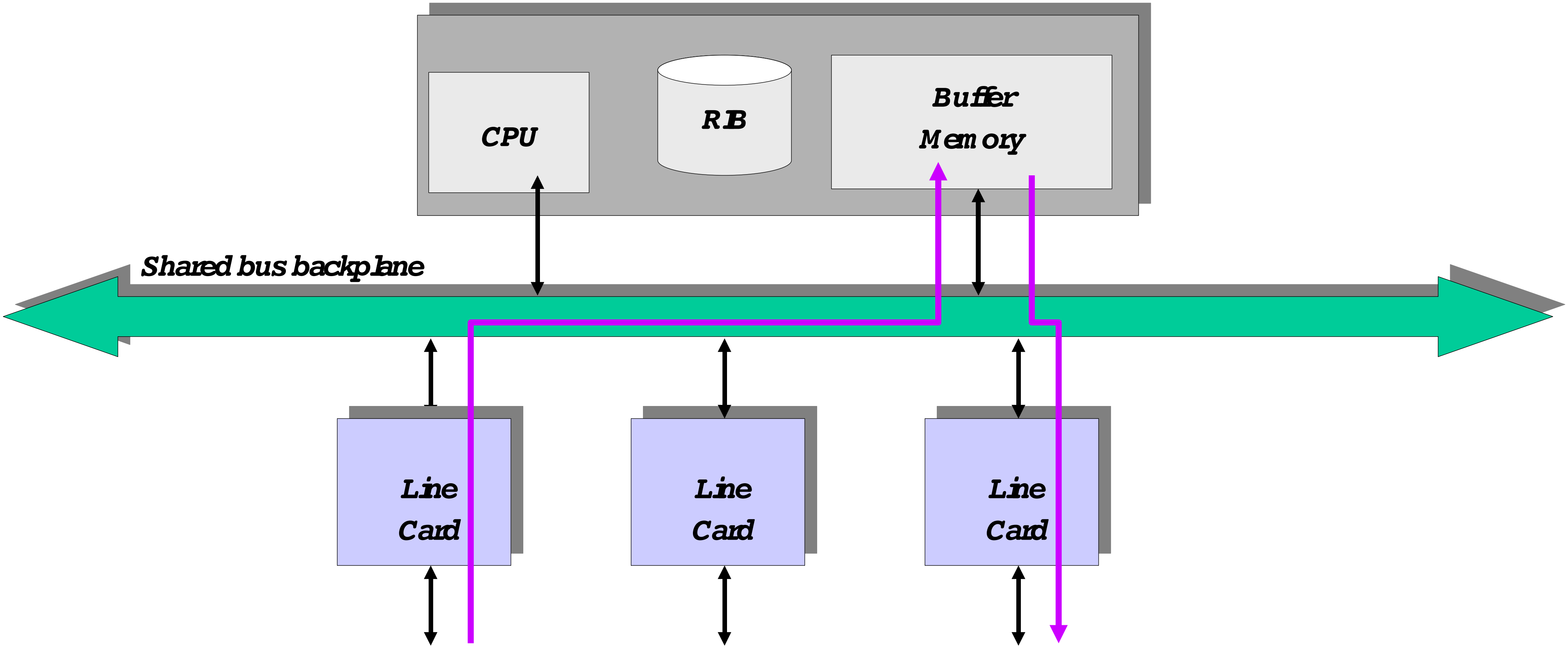


Inside a router, HW style



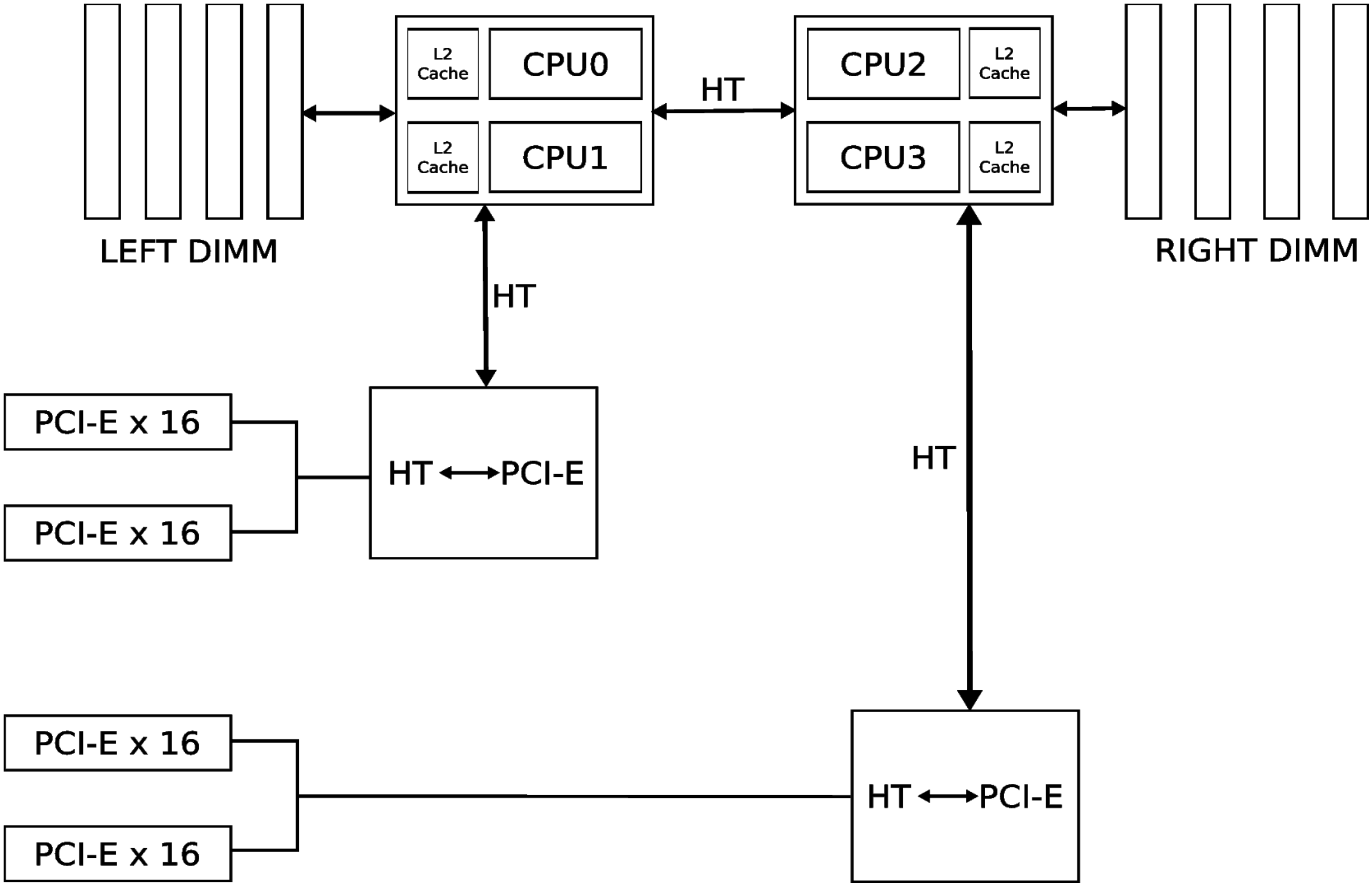
Specialized hardware: ASICs, NPUs, backplane with switching stages or crossbars

Inside a router, PC-style



- Every packet goes twice over shared bus to the CPU
- Cheap, but low performance
- But lets increase the # of CPUs and # of buses!

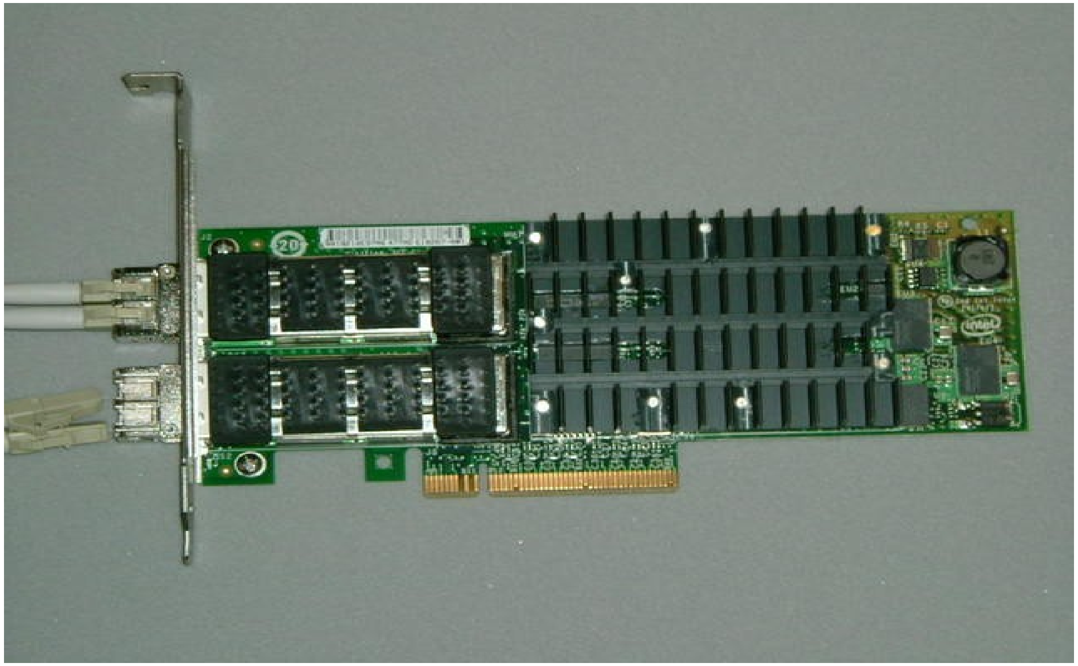
Block hw structure (set 1)



Hardware – Box (set 2)

AMD Opteron 2356 with one quad core 2.3GHz Barcelona CPUs on a TYAN 2927 Motherboard (2U)

Hardware - NIC



Intel 10g board Chipset 82598

Open chip specs. Thanks Intel!

Lab

Equipment summary

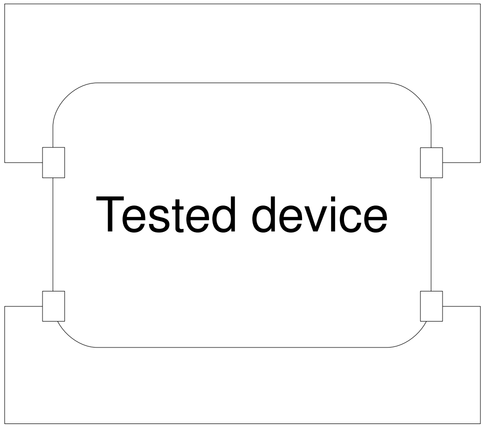
- Hardware needs to be carefully selected
- BifrostLinux on kernel 2.6.24rc7 with LC-trie forwarding
- Tweaked pktgen
- Set 1: AMD Opteron 2222 with two double core 3GHz CPUs on a Tyan Thunder n6650W(S2915) motherboard
- Set 2: AMD Opteron 2356 with one quad core 2.3GHz Barcelona CPUs on a TYAN 2927 Motherboard (2U)
- Dual PCIe buses
- 10GE network interface cards.
  - PCI Express x8 lanes based on Intel 82598 chipset

Experiments

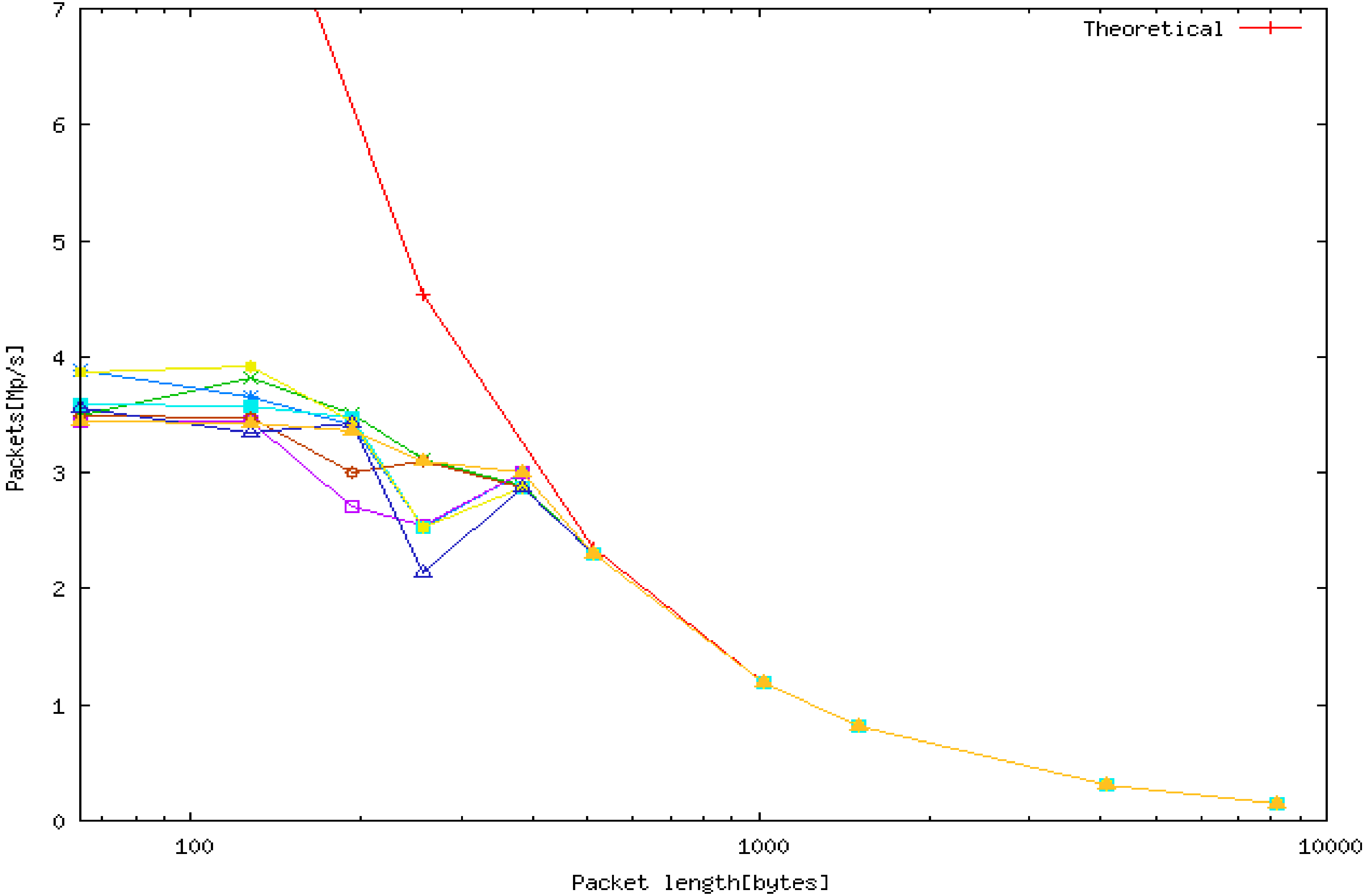
- Transmission(TX)
  - Upper limits on (hw) platform
- Forwarding experiments
  - Realistic forwarding performance

Tx Experiments

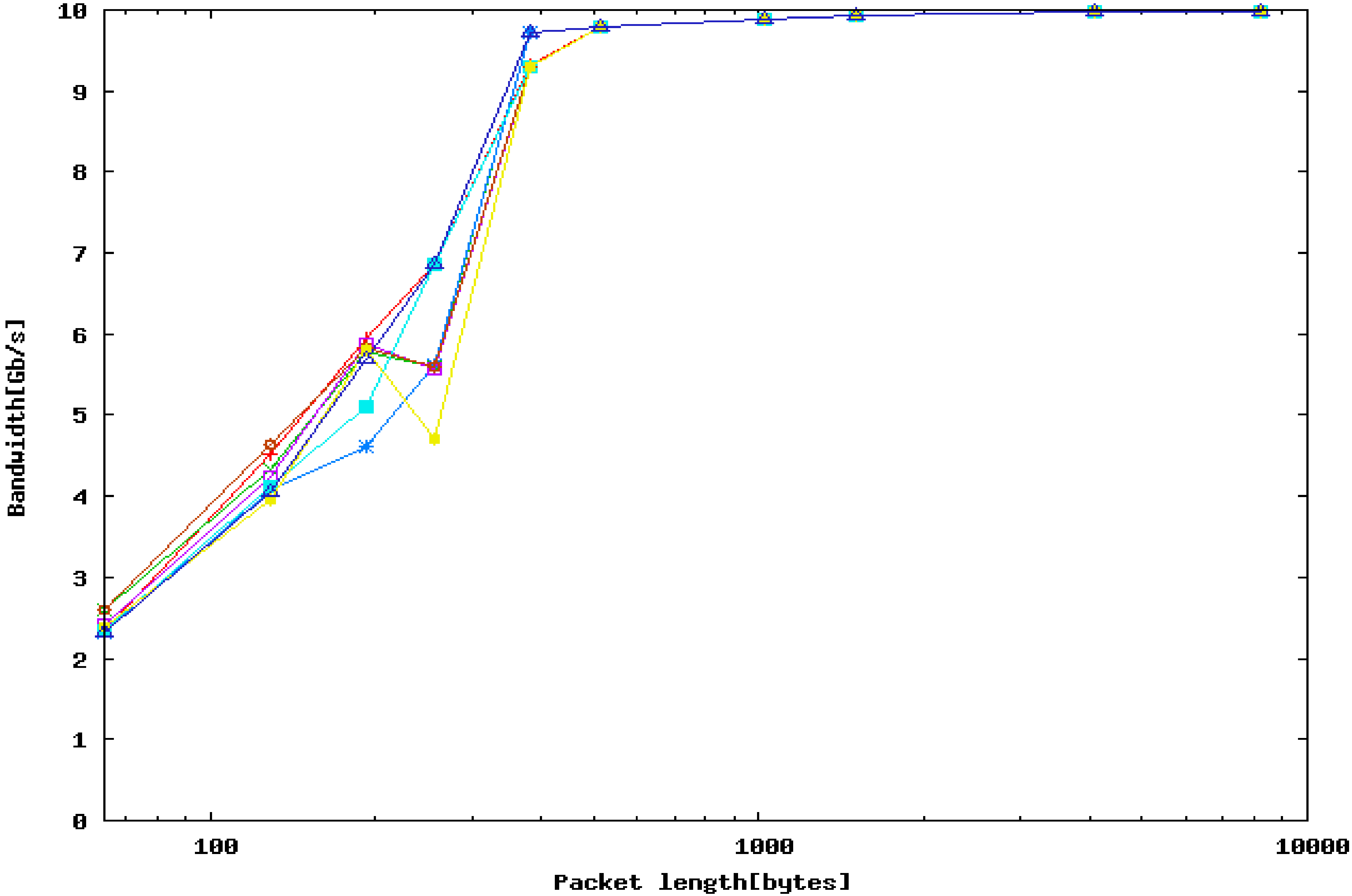
- Goal:
  - Just to see how much the hw can handle – upper limit
- Loopback tests over fibers
- Don't process RX packets just let MAC count them
- These numbers can give indication what forwarding capacity is possible
- Experiments:
  - Single CPU TX single interface
  - Four CPUs TX one interface each

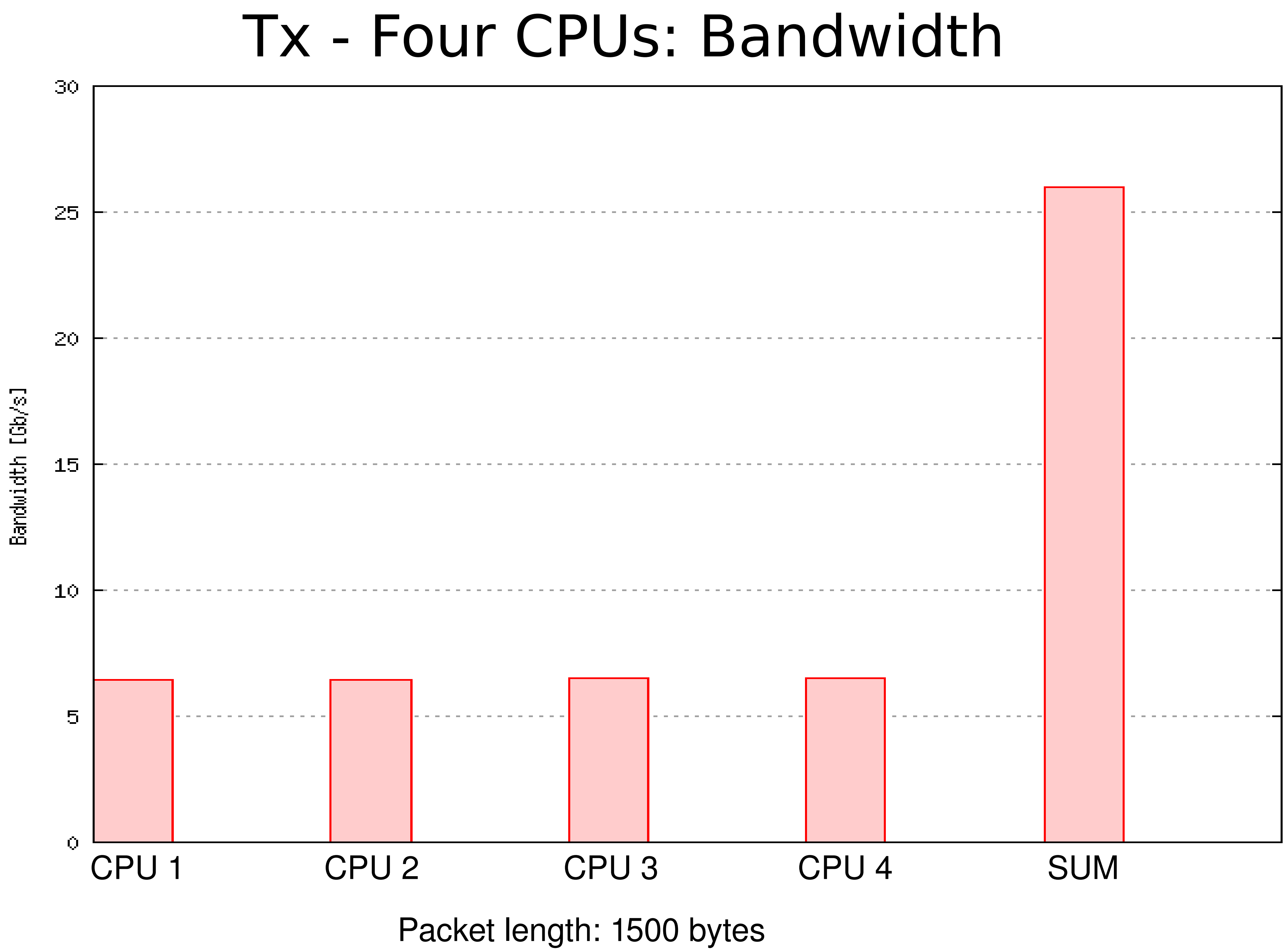


Tx single sender: Packets per second



Tx single sender: Bandwidth



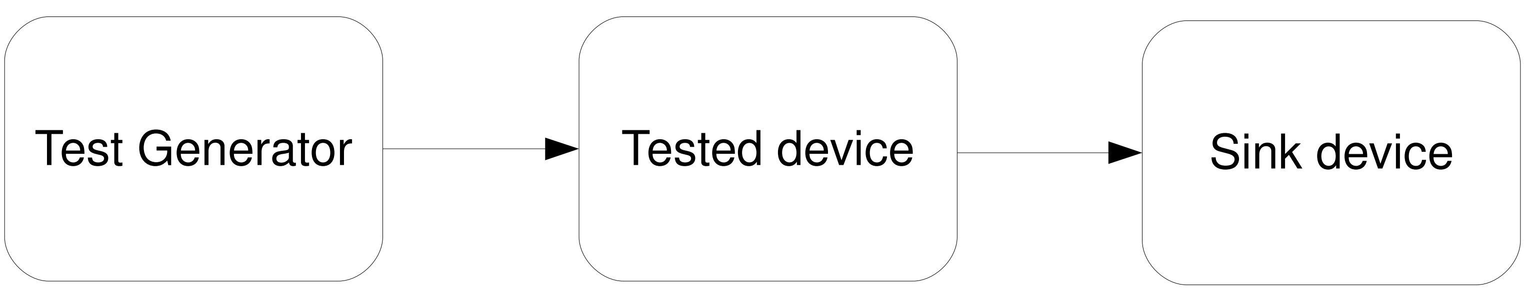

Tx - Four CPUs: Bandwidth
Bandwidth [Gb/s]
30
25
20
15
10
5
0
CPU 1
CPU 2
CPU 3
CPU 4
SUM
Packet length: 1500 bytes

TX experiments summary

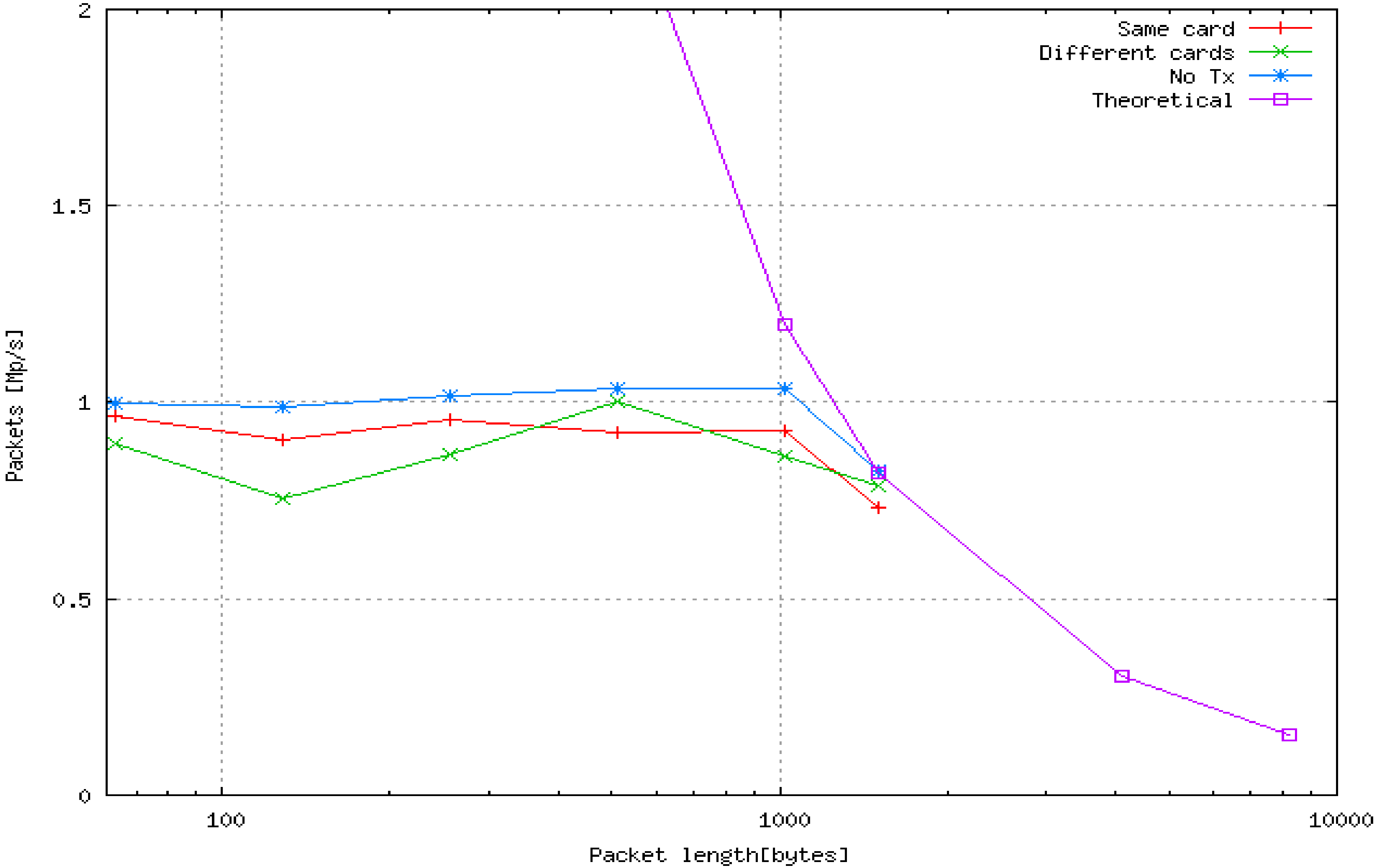
- Single Tx sender is primarily limited by PPS at around 3.5Mpps
- A bandwidth of 25.8 Gb/s and a packet rate of 10 Mp/s using four CPU cores and two PCIe buses
- This shows that the hw itself allows 10Gb/s performance
- We also see nice symmetric Tx between the CPU cores.

Forwarding experiments

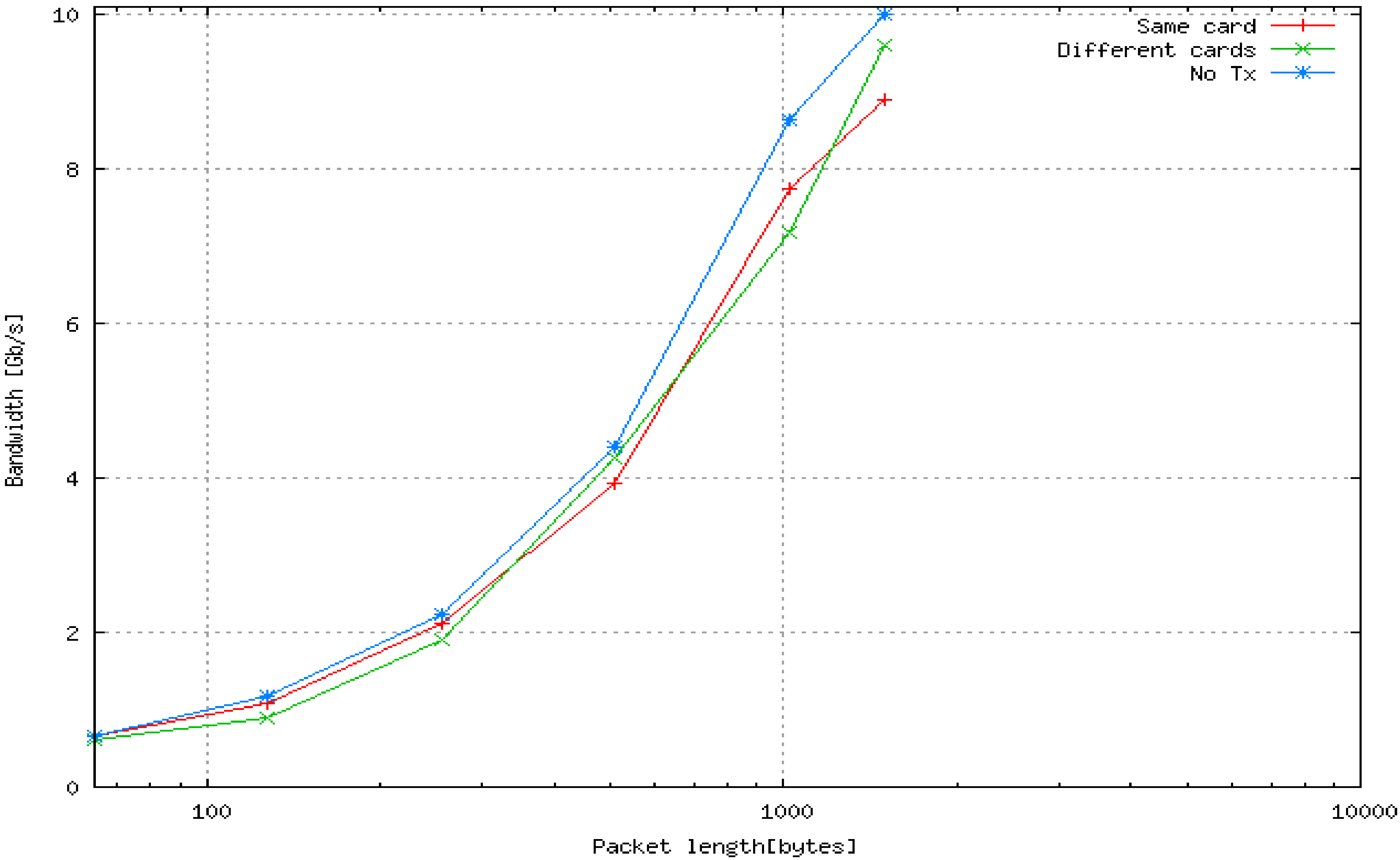
- Goal:
  - Realistic forwarding performance
- Overload measurements (packets are lost)
- Single forwarding path from one traffic source to one traffic sink
  - Single IP flow was forwarded using a single CPU.
  - Realistic multiple-flow stream with varying destination address and packet sizes using a single CPU.
  - Multi-queues on the interface cards were used to dispatch different flows to four different CPUs.



Single flow, single CPU: Packets per second



Single flow, single CPU: Bandwidth



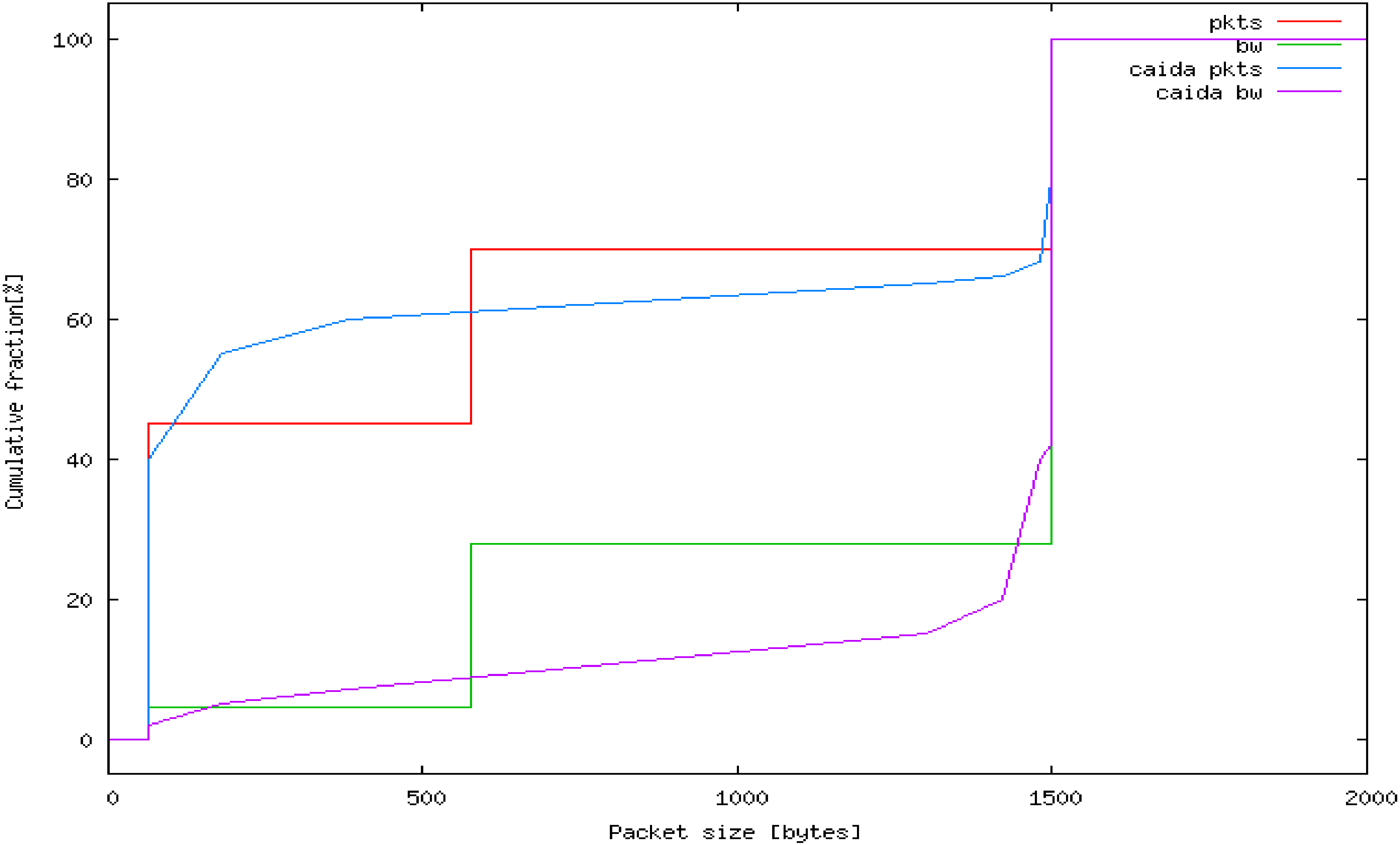
Single sender forwarding summary

- Virtually wire-speed for 1500-byte packets
- Little difference between forwarding on same card, different ports, or between different cards
  - Seems to be slightly better perf on same card, but not significant
- Primary limiting factor is pps, around 900Kpps
- TX has small effect on overall performance

Introducing realistic traffic

- For the rest of the experiments we introduce a more realistic traffic scenario
- Multiple packet sizes
  - Simple model based on realistic packet distribution data
- Multiple flows (multiple dst IP:s)
  - This is also necessary for multi-core experiments since NIC classification is made using hash algorithm on packet headers

Packet size distribution (cdf)

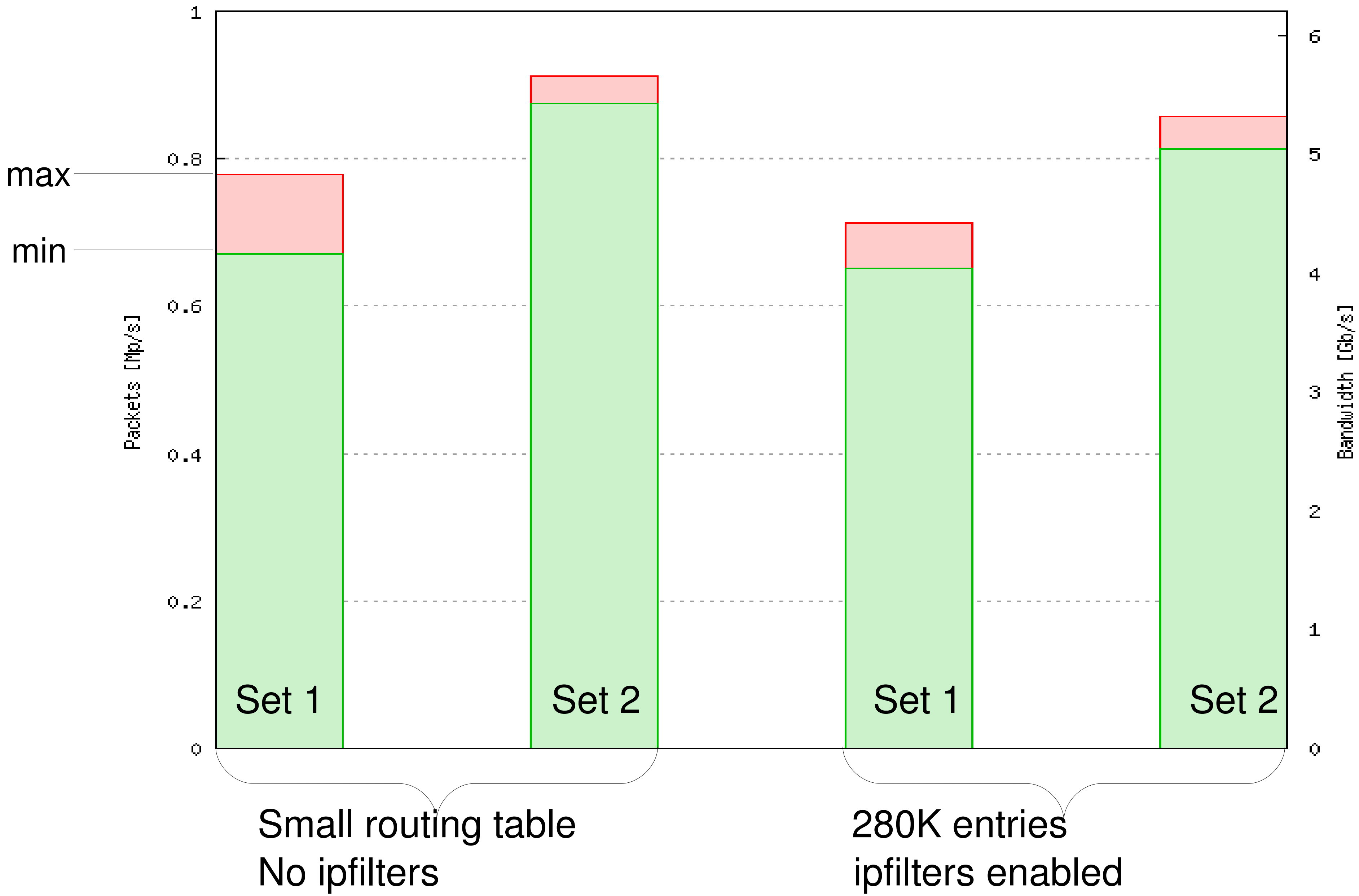


Real data from www.caida.org, Wide aug 2008

Flow distribution

- Flows have size and duration distributions
- 8000 simultaneous flows
- Each flow 30 packets long
  - Mean flow duration is 258 ms
- 31000 new flows per second
  - Measured by dst cache misses
- Destinations spread randomly over 11.0.0.0/8
- FIB contains ~ 280K entries
  - 64K entries in 11.0.0.0/8
- This flow distribution is relatively aggressive

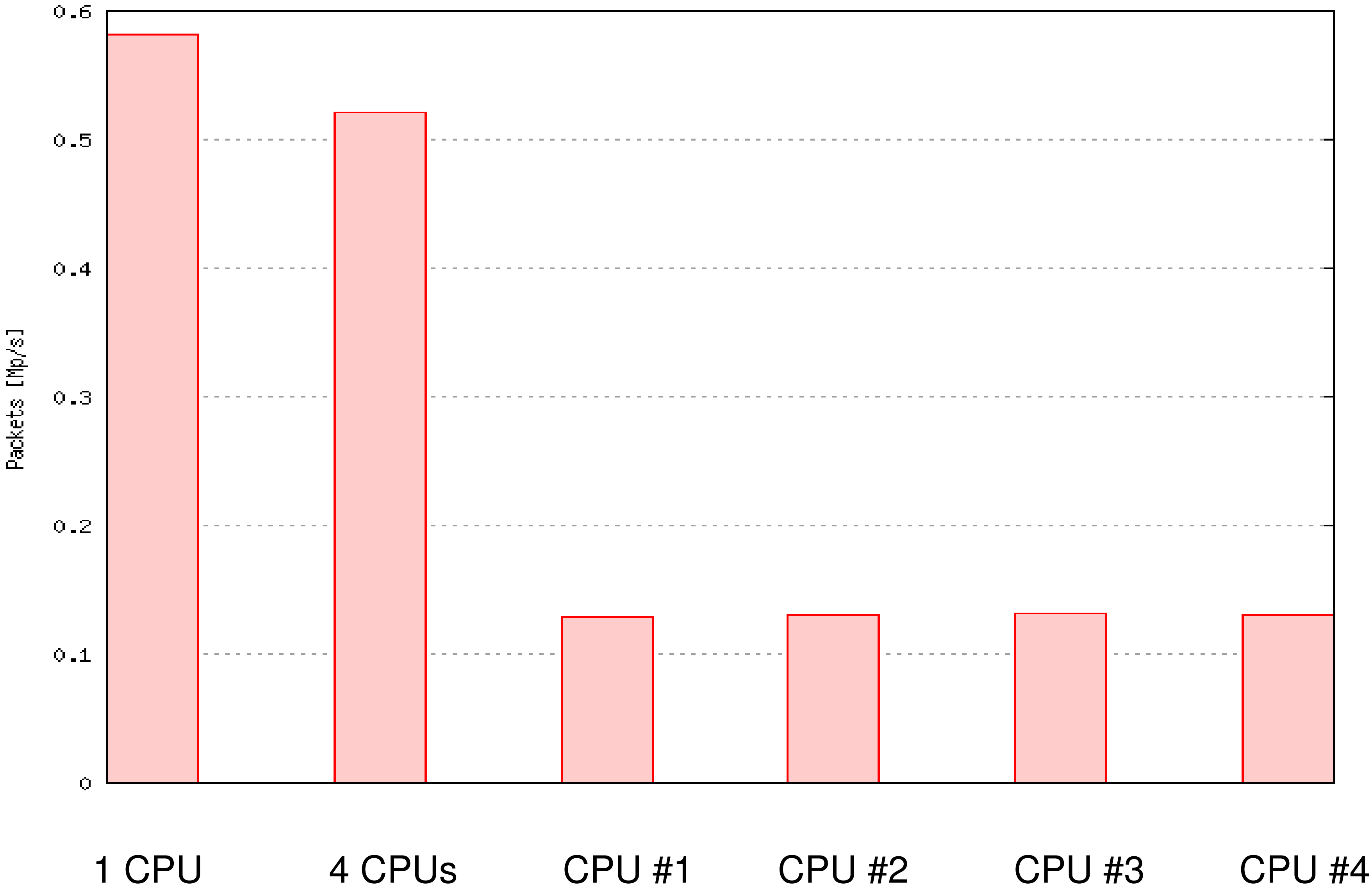
Multi-flow and single-CPU: PPS & BW



Multi-Q experiments

- Use more CPU cores to handle forwarding
- NIC classification (Receiver Side Scaling RSS) uses hash algorithm to select input queue
- Allocate several interrupt channels, one for each CPU.
- Flows are distributed evenly between CPUs
  - need aggregated traffic with multiple flows
- Questions:
  - Are processing of flows evenly dispatched ?
  - Will performance increase as CPUs are added?

Multi-flow and Multi-CPU (set 1)



Only 64 byte packets

Results MultiQ

- Packets are evenly distributed between the four CPUs.
- But forwarding using one CPU is better than using four CPUs!
- Why is this?

Profiling.

Single CPU

samples	%	symbol name
396100	14.8714	kfree
390230	14.6510	dev_kfree_skb_irq
300715	11.2902	skb_release_data
156310	5.8686	eth_type_trans
142188	5.3384	ip_rcv
106848	4.0116	__alloc_skb
75677	2.8413	raise_softirq_irqoff
69924	2.6253	nf_hook_slow
69547	2.6111	kmem_cache_free
68244	2.5622	netif_receive_skb

Multiple CPUs

samples	%	symbol name
1087576	22.0815	dev_queue_xmit
651777	*13.2333*	*__qdisc_run*
234205	4.7552	eth_type_trans
204177	4.1455	dev_kfree_skb_irq
174442	3.5418	kfree
158693	3.2220	netif_receive_skb
149875	3.0430	pfifo_fast_enqueue
116842	2.3723	ip_finish_output
114529	2.3253	__netdev_alloc_skb
110495	2.2434	cache_alloc_refill

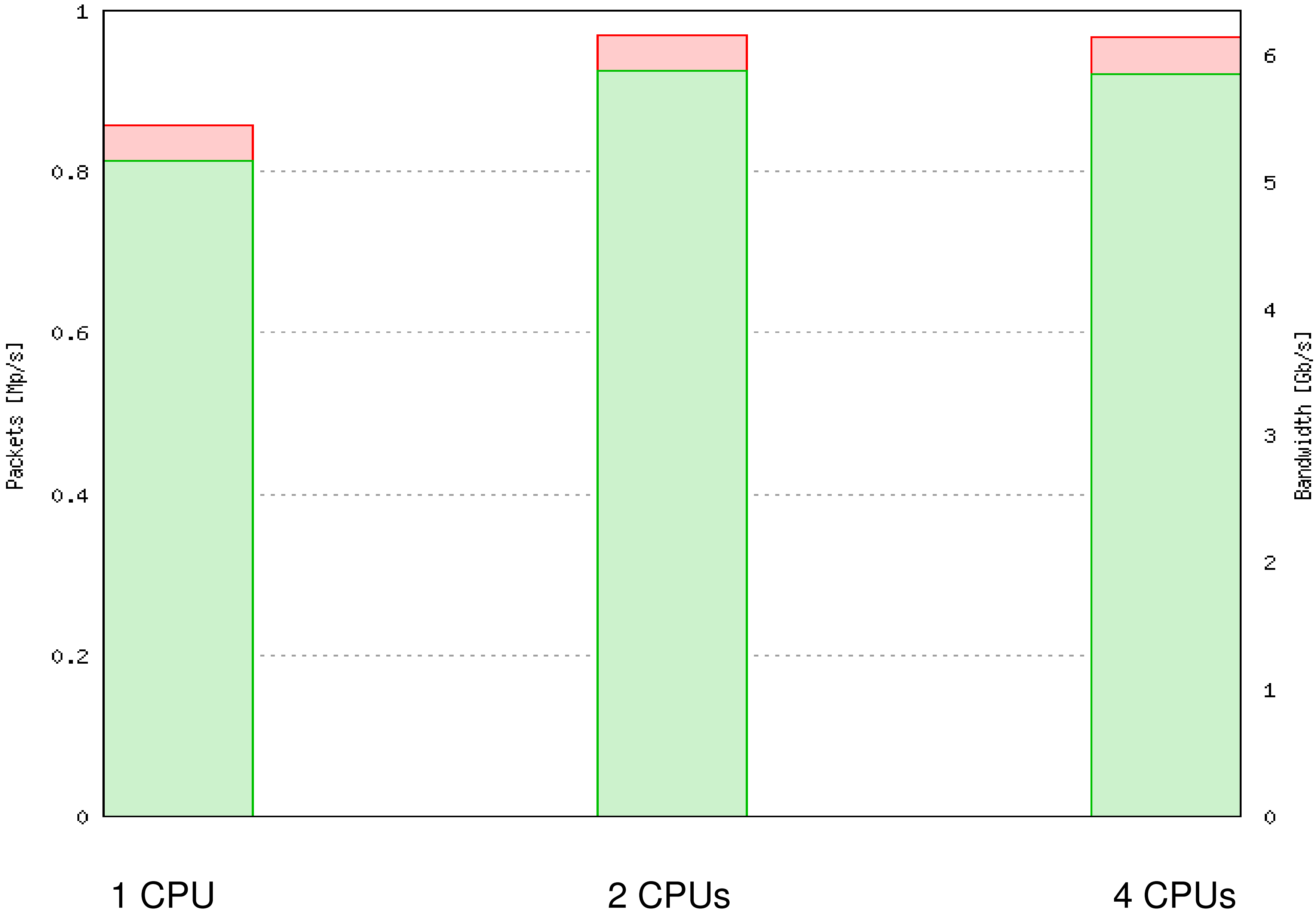
Multi-Q analysis

- With multiple CPUs: TX processing is using a large part of the CPU making using more CPUs sub-optimal
- It turns out that the Tx and Qdisc code needs to be adapted to scale up performance

MultiQ: Updated drivers

- We recently made new measurements (not in paper) using updated driver code
- We also used hw set 2 (Barcelona) to get better results
- We now see an actual improvement when we add one processor
- (More to come)

Multi-flow and Multi-CPU (set 2)



Conclusions

- Tx and forwarding results towards 10Gb/s performance using Linux and selected hardware
- For optimal results hw and sw must be carefully selected.
- >25Gb/s Tx performance
- Near 10Gb/s wirespeed forwarding for large packets
- Identified bottleneck for multi-q and multi-core forwarding.
- If this is removed, upscaling performance using several CPU cores is possible to 10Gb/s and beyond.