Optimizing igb and ixgbe network driver scaling performance

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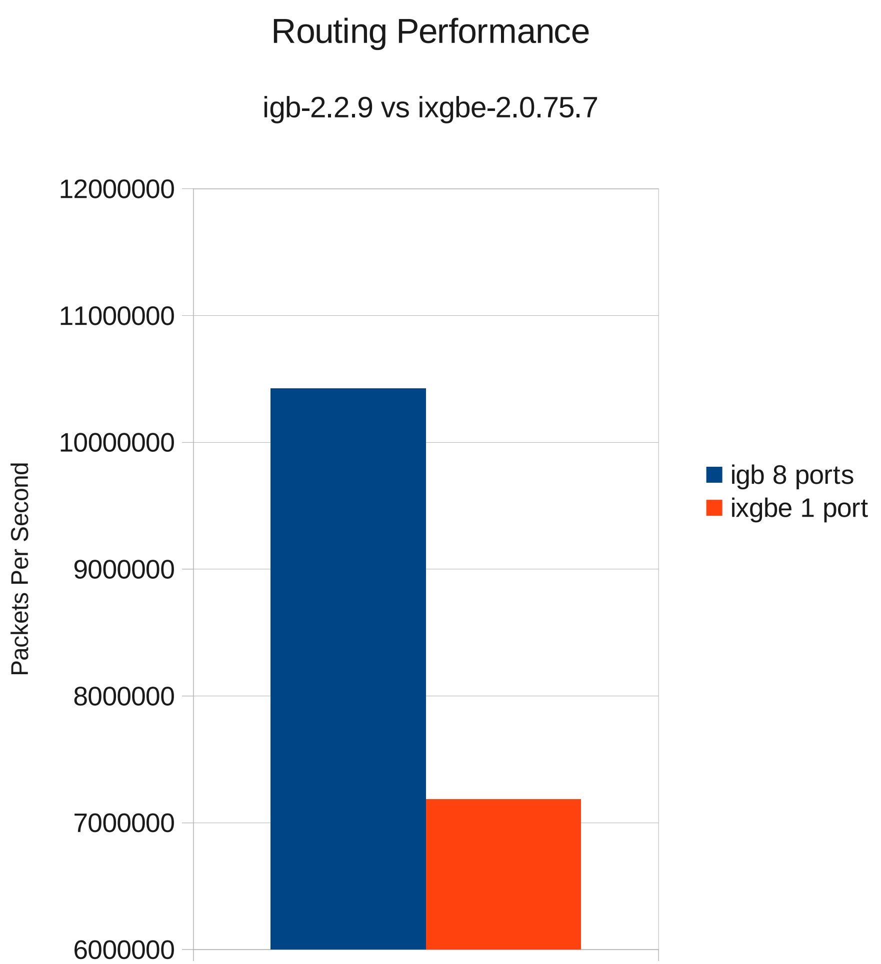
Agenda

- The state of the igb and ixgbe drivers then and now
- Configuring the kernel and system for best performance
- Getting to the root cause of the performance improvements
- Where we still might have room to improve

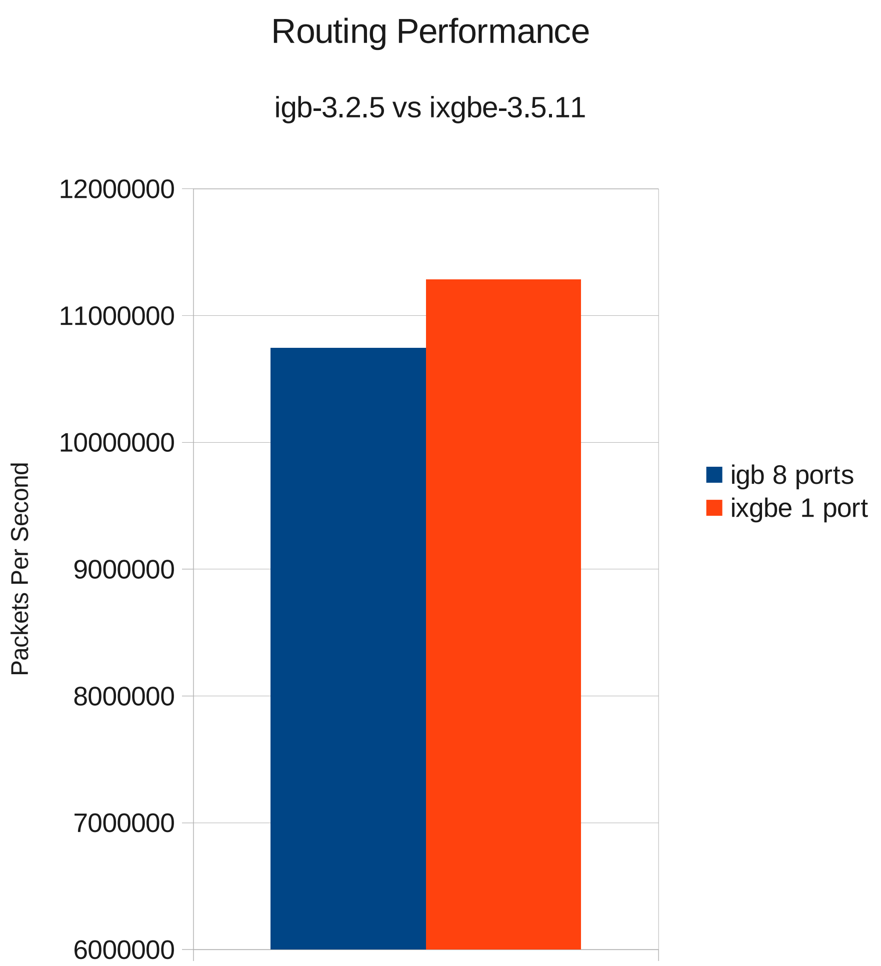
The state of igb & ixgbe over a year ago

- Problem: igb was over 40% faster than the ixgbe.
- Solution: Refactor ixgbe to more closely match igb.



The state of igb & ixgbe now

- Mission accomplished!
- How did we get from there to here?
- Could we be masking over some other issues?
- Where do we go from here?



Configuring the kernel for best performance

- Disable any and all config options that add to the size of the sk_buff w/o any benefit to your testing
  - Ipv6, IPSEC, IOAT, Netfilter, Qos support, and network actions
  - Result should be an sk_buff that fits in 3 cache lines
  - May be unrealistic but we are testing the drivers, not the stack
- Disable IOMMU
  - Generates significant DMA map/unmap overhead
  - May also be disabled via kernel parameter

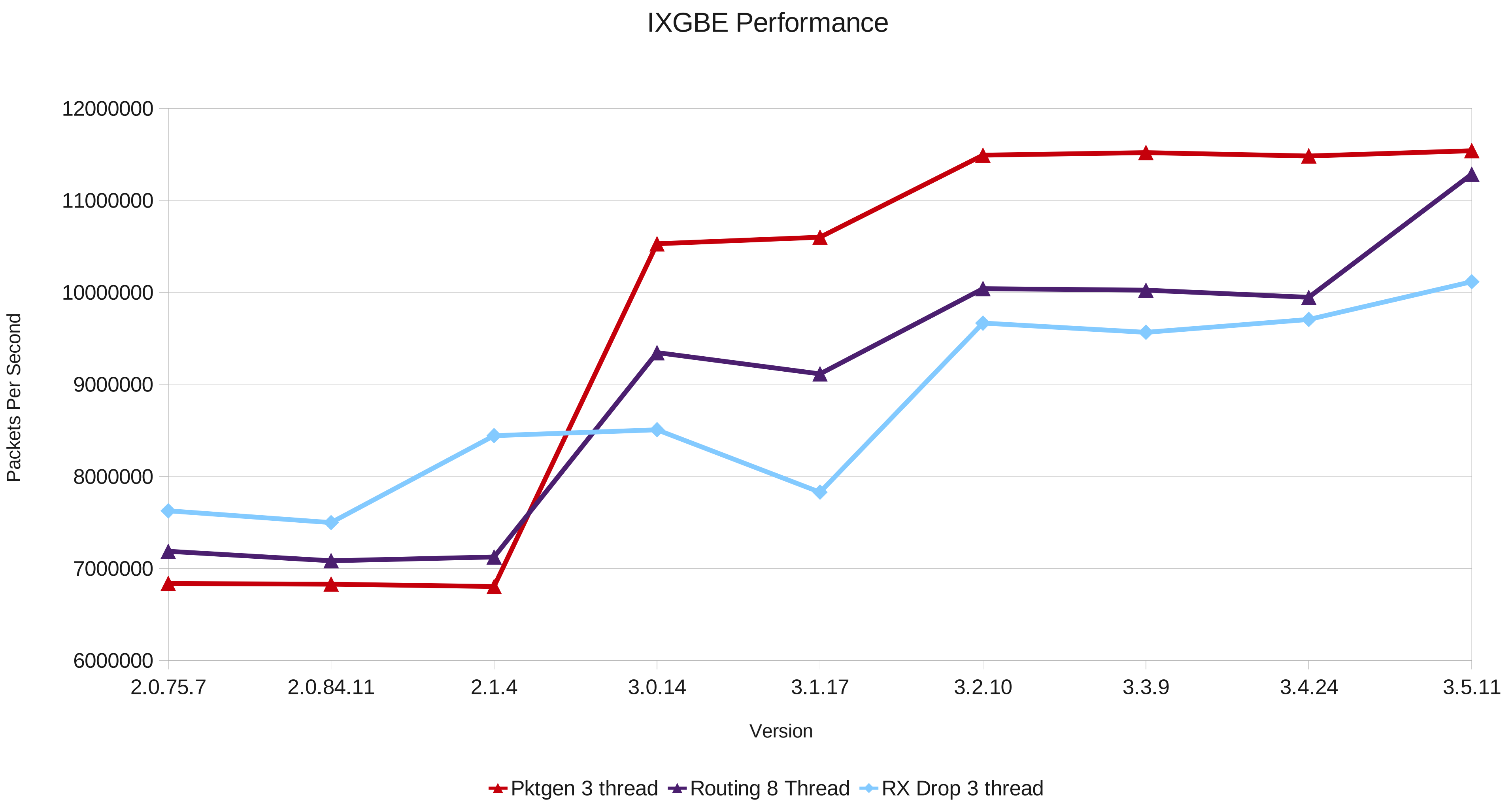
Configuring the system for best performance

- Evenly load the nodes and memory channels with memory
  - The test system had 2 nodes with 3 channels of memory each.
  - I loaded 1 2G DIMM of memory on each channel for a total of 12GB
- Evenly distribute device interrupts on CPUs
  - set_irq_affinity.sh script included with ixgbe driver can now handle this task

The test configuration

- System running dual Xeon X5680 @ 3.33Ghz
  - Running 2.6.35.14 kernel
  - Connected back to back with Spirent Smartbits 6000c containing a XLW-3720a card
  - Tests typically ran with 64 simultaneous UDP streams
- 3 Basic tests
  - 3 Queue pktgen
  - 3 Queue receive & drop at ip_rcv
  - 8 Queue bidirectional single port routing
- Why select only 3/8 queues?
  - They had not reached line rate in any tests I was running
  - Routing showed that the stack consumed about 25% of the total
  - Thus I end up with 3 CPUs RX, 3 CPUs TX, and 2 CPUs stack

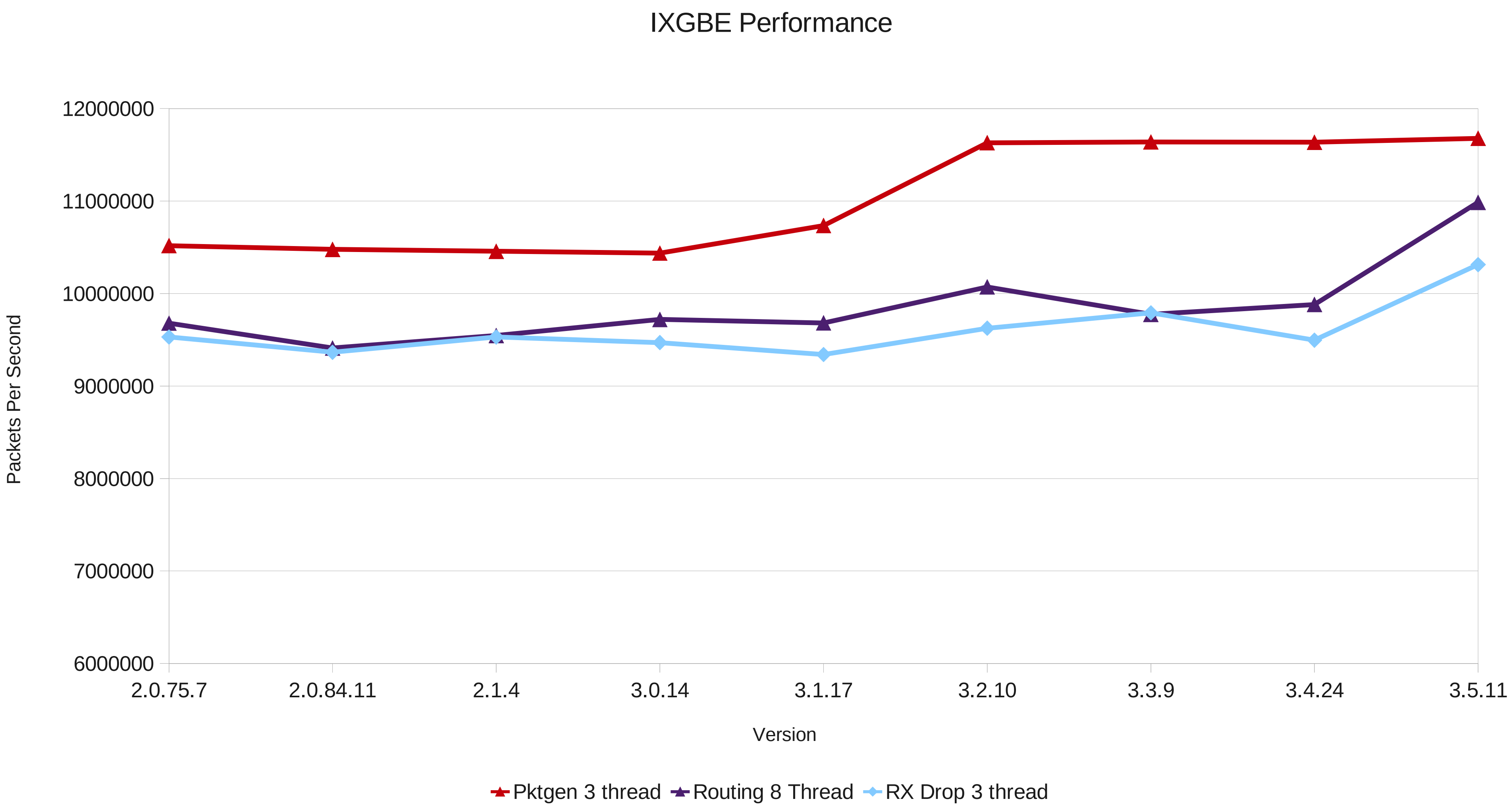
Results, Round 1



Something doesn't seem right..

- 2.1.4
  - Dropped support for RSS w/ UDP ports
    - This changed the work distribution
- 3.0.14
  - Removed trans_start from Tx path
    - This change was pushed upstream over a year prior
- 3.2.10
  - Removed last_rx from Rx path
    - Another change that made it upstream over a year prior

Results, Round 2



Performance root cause

- 3.1.17
  - Set TXDCTL.PTHRESH to 32, allowing hardware to prefetch descriptors in groups of 8.
- 3.2.10
  - Combined all hotpath items in adapter struct into a single read-mostly cacheline
- 3.5.11
  - Enabled SRRCTL.DROP_EN when RX multiqueue is enabled and flow control is disabled

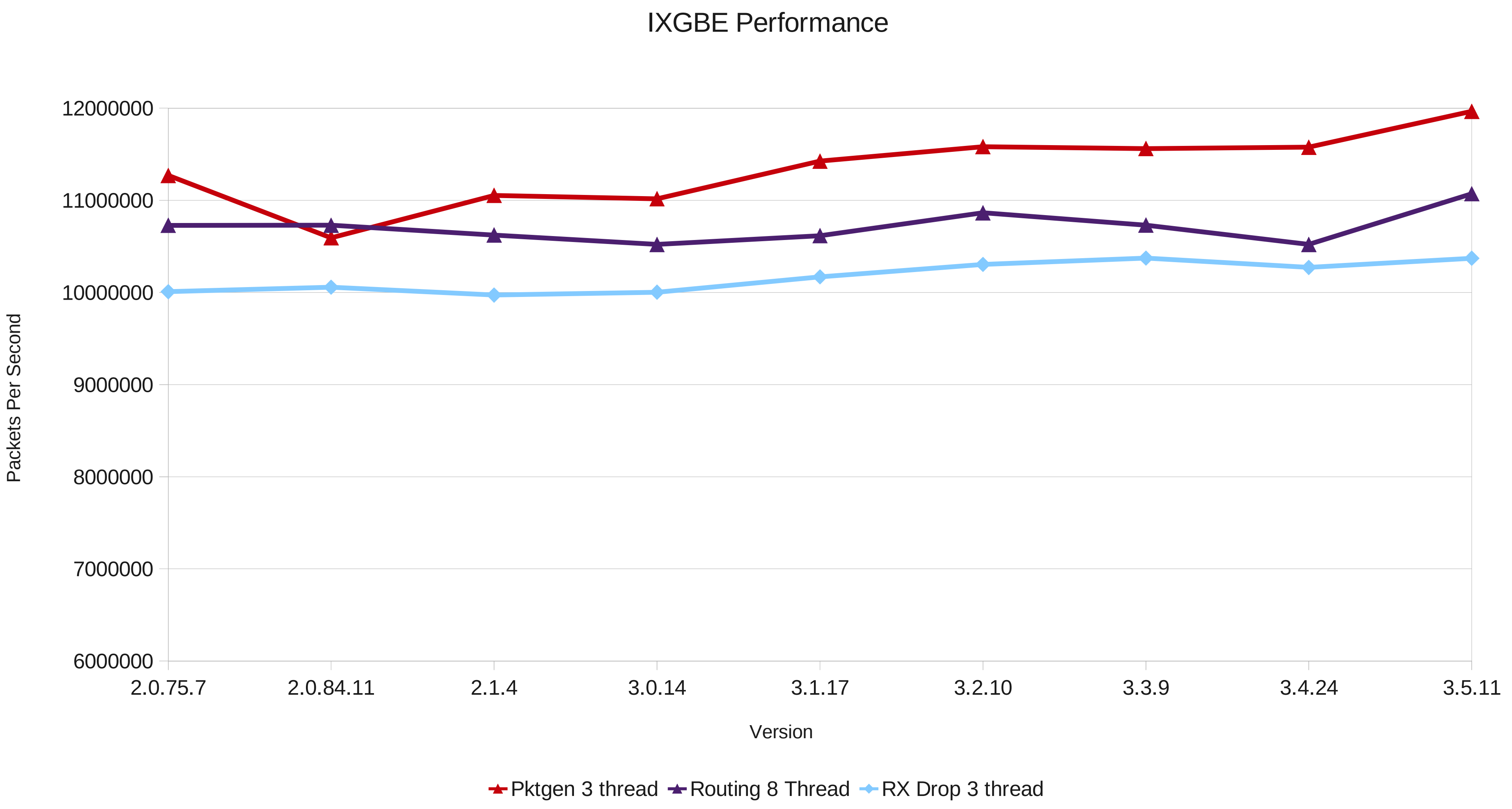
Cutting the memory overhead

- Combine all adapter fields accessed in hot-path into single cache-line to prevent cache pollution
- Configure hardware to batch descriptor reads & writes

Knowing when to drop a packet

- Rx FIFO is yet another buffer that can introduce delays
  - Prone to head of line blocking in multiqueue configurations
  - Can only move as fast as the quickest ring
- SRRCTL.DROP_EN drops packets from Rx FIFO
  - Only drops packets when no buffers are available on ring to DMA to
  - Allows faster rings to keep processing while slower rings drop packets
  - Reduces overall dropped packet rate
  - Mutually exclusive with features like flow control and DCB

Results, Round 3



Performance root cause

- 2.0.84.11
  - Performance regression due to alignment change of ixgbe_clean_tx_irq from 64 byte to 16 byte
- 3.1.17
  - Combined ixgbe_tx_map and ixgbe_tx_queue calls into a single function
  - Fused all NAPI cleanup into ixgbe_poll
  - General cleanup of TX and RX path
- 3.5.11
  - Store values in “first” tx_buffer_info struct sooner
  - Avoid unecessary modification of TX descriptor in cleanup

Reduce & reuse to cut memory usage

- Store values in the Tx buffer_info structure instead of in the stack
- Make Tx/Rx cleanup paths leave descriptors rings untouched until new buffers are available
- Reduce memory reads in Tx path by separating read-mostly and write-mostly parts of the ring structure
- Allocate memory on local node to reduce memory access time
- Allocate sk_buff such that skb->head is fully used
  - sizes 512, 1.5K, 3K, 7K, & 15K are optimal
- Use only ½ of a page to allow for page reuse via page user count

Reducing code complexity

ixgbe-2.0.75.7

ixgbe_msix_clean_tx
ixgbe_msix_clean_rx
ixgbe_msix_clean_many

ixgbe_poll
ixgbe_clean_txonly
ixgbe_clean_rxonly
ixgbe_clean_rxtx_many

ixgbe-3.5.11

ixgbe_msix_clean_rings

ixgbe_poll

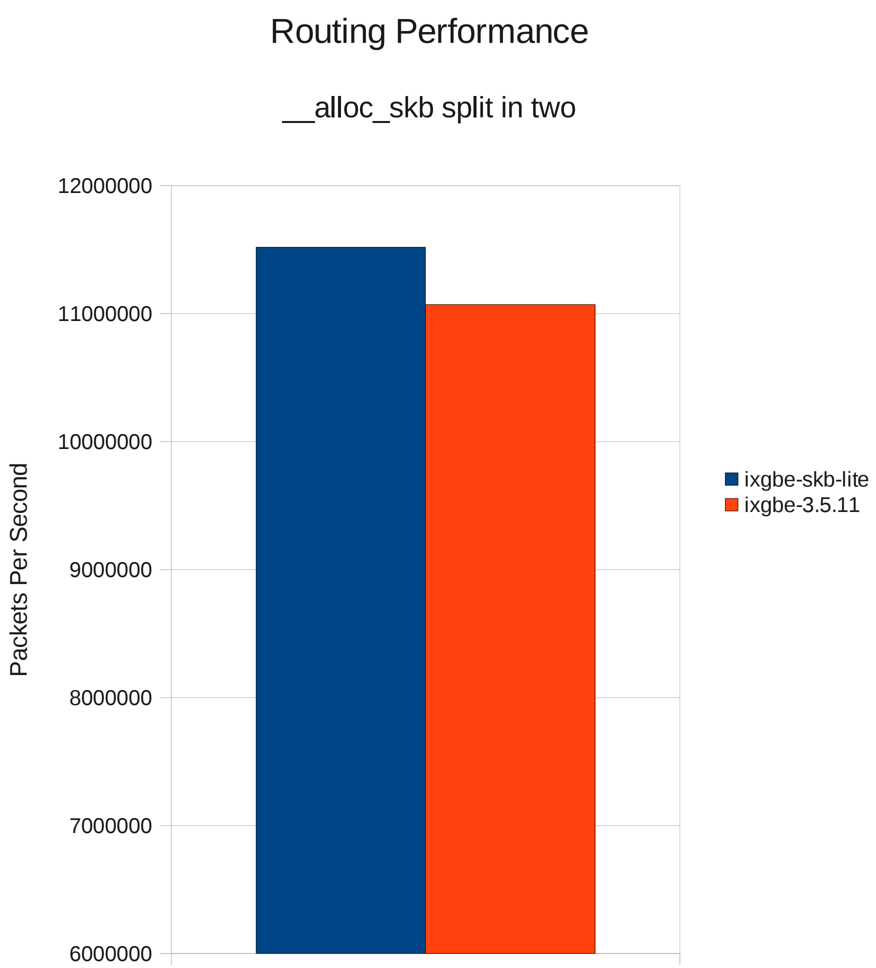
- Avoid unnecessary duplication of effort in maintenance.
- By only having one ixgbe_poll call the compiler can optimize by in-lining all of the various functions used by the call.

Where do we still have room to improve?

- At this point ixgbe consumes only about 15% of the total CPU utilization
- Duplicate overhead in ixgbe_poll and __alloc_skb due to cache misses while zeroing & reading skb header
- 90% of spin lock overhead appears to be due to Qdisc lock taken in sch_direct_xmit

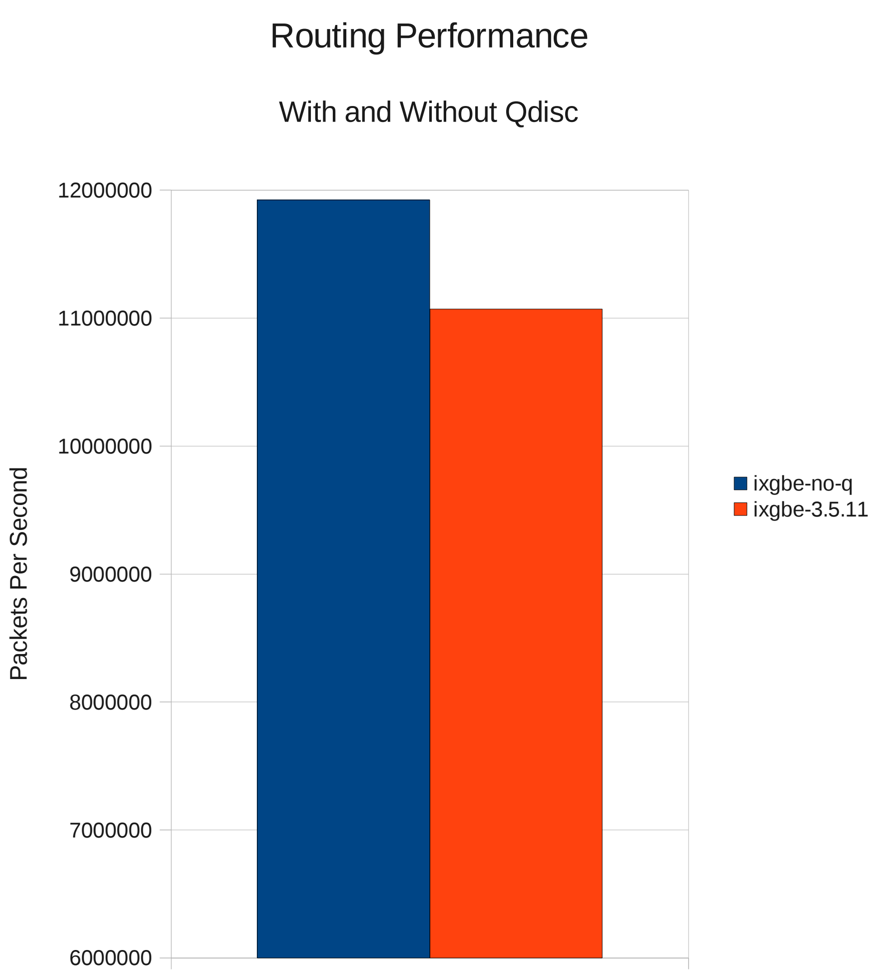
```
20.14%   [k] _raw_spin_lock
 7.76%   [k] ixgbe_poll
 6.58%   [k] eth_type_trans
 4.69%   [k] __alloc_skb
 4.68%   [k] ip_rcv
 4.36%   [k] ixgbe_xmit_frame_ring
 3.48%   [k] ip_forward
 3.37%   [k] ip_route_input_common
 3.30%   [k] dev_queue_xmit
 3.24%   [k] kfree
 3.03%   [k] __netif_receive_skb
 2.81%   [k] kmem_cache_free
 2.70%   [k] kmem_cache_alloc_node
 2.56%   [k] kmem_cache_alloc_node_notrace
 1.93%   [k] ixgbe_alloc_rx_buffers
 1.93%   [k] __phys_addr
 1.73%   [k] memcpy
 1.73%   [k] skb_release_data
 1.32%   [k] ixgbe_select_queue
 1.30%   [k] dev_hard_start_xmit
 1.26%   [k] swiotlb_dma_mapping_error
 1.14%   [k] ip_finish_output
 1.08%   [k] __kmalloc_node
 1.03%   [k] local_bh_enable
```

What if we delay skb init?




```
20.84%  [k] _raw_spin_lock
 8.56%  [k] ixgbe_poll
 5.38%  [k] ixgbe_xmit_frame_ring
 4.40%  [k] ip_rcv
 3.90%  [k] eth_type_trans
 3.85%  [k] kfree
 3.83%  [k] dev_queue_xmit
 3.45%  [k] ip_route_input_common
 2.98%  [k] kmem_cache_free
 2.89%  [k] __netif_receive_skb
 2.83%  [k] kmem_cache_alloc_node_notrace
 2.68%  [k] kmem_cache_alloc_node
 2.25%  [k] ip_forward
 2.24%  [k] __phys_addr
 1.79%  [k] memcpy
 1.78%  [k] ixgbe_alloc_rx_buffers
 1.57%  [k] is_swiotlb_buffer
 1.52%  [k] dev_hard_start_xmit
 1.36%  [k] init_skb_lite
 1.36%  [k] skb_release_data
 1.33%  [k] swiotlb_map_page
 1.14%  [k] ip_finish_output
 1.11%  [k] __alloc_skb_lite
 1.10%  [k] local_bh_enable
```

What if we didn't have a Qdisc?




```
22.26%  [k] ixgbe_poll
 5.95%  [k] ip_rcv
 5.12%  [k] __alloc_skb
 4.97%  [k] ixgbe_xmit_frame_ring
 4.54%  [k] __netif_receive_skb
 3.78%  [k] ip_route_input_common
 3.69%  [k] kfree
 3.62%  [k] kmem_cache_alloc_node
 3.48%  [k] ip_forward
 3.26%  [k] kmem_cache_free
 2.78%  [k] kmem_cache_alloc_node_notrace
 2.69%  [k] eth_type_trans
 2.49%  [k] dev_queue_xmit
 2.23%  [k] __phys_addr
 2.14%  [k] ixgbe_alloc_rx_buffers
 1.91%  [k] memcpy
 1.69%  [k] _raw_spin_lock
 1.68%  [k] skb_release_data
 1.51%  [k] dev_hard_start_xmit
 1.35%  [k] swiotlb_map_page
 1.21%  [k] ip_finish_output
 1.14%  [k] __kmalloc_node
 1.07%  [k] swiotlb_dma_mapping_error
 1.01%  [k] is_swiotlb_buffer
```