School of Computer Science & Engineering

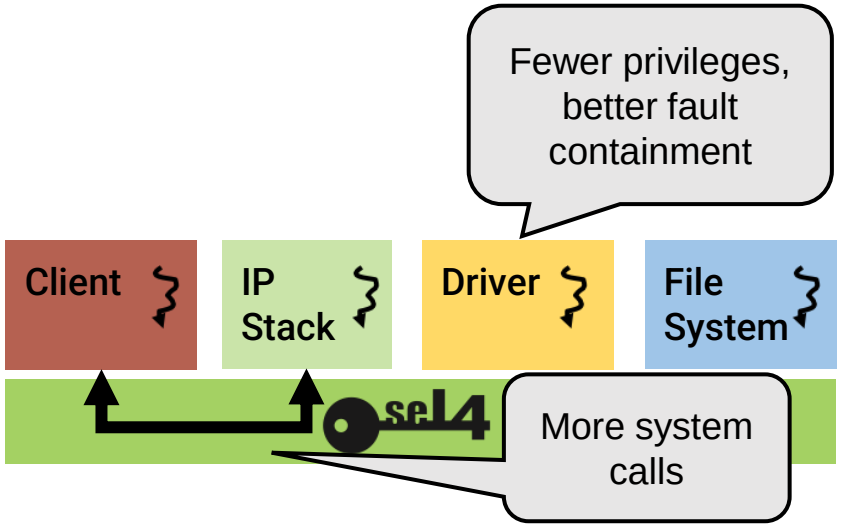
Trustworthy Systems Group

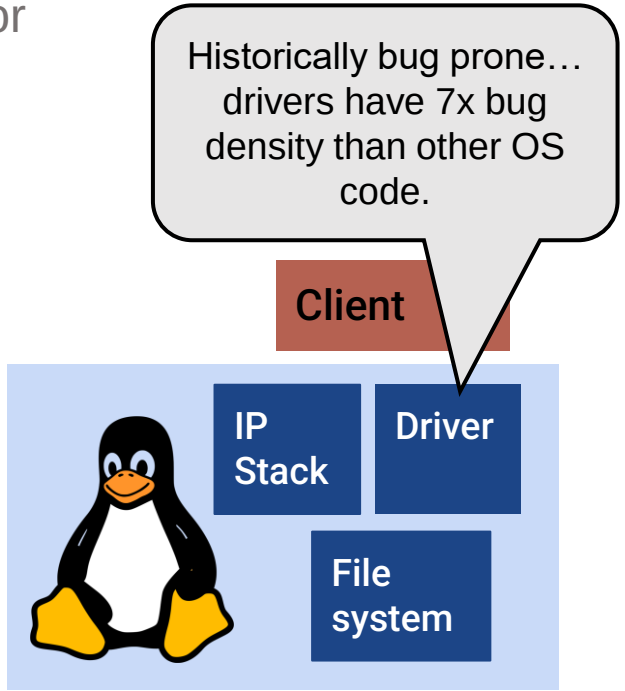
The seL4 Device Driver Framework

Lucy Parker
lucy.parker@student.unsw.edu.au

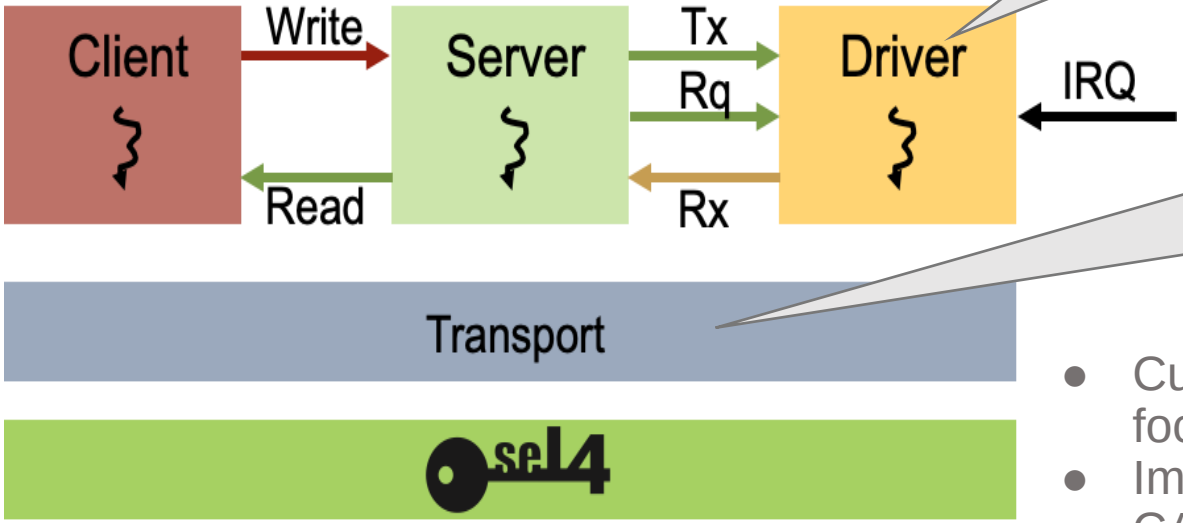
What Is The seL4 Device Driver Framework?

Framework to provide interfaces and protocol for writing performant device drivers as seL4 user level programs.





What Is The sDDF?



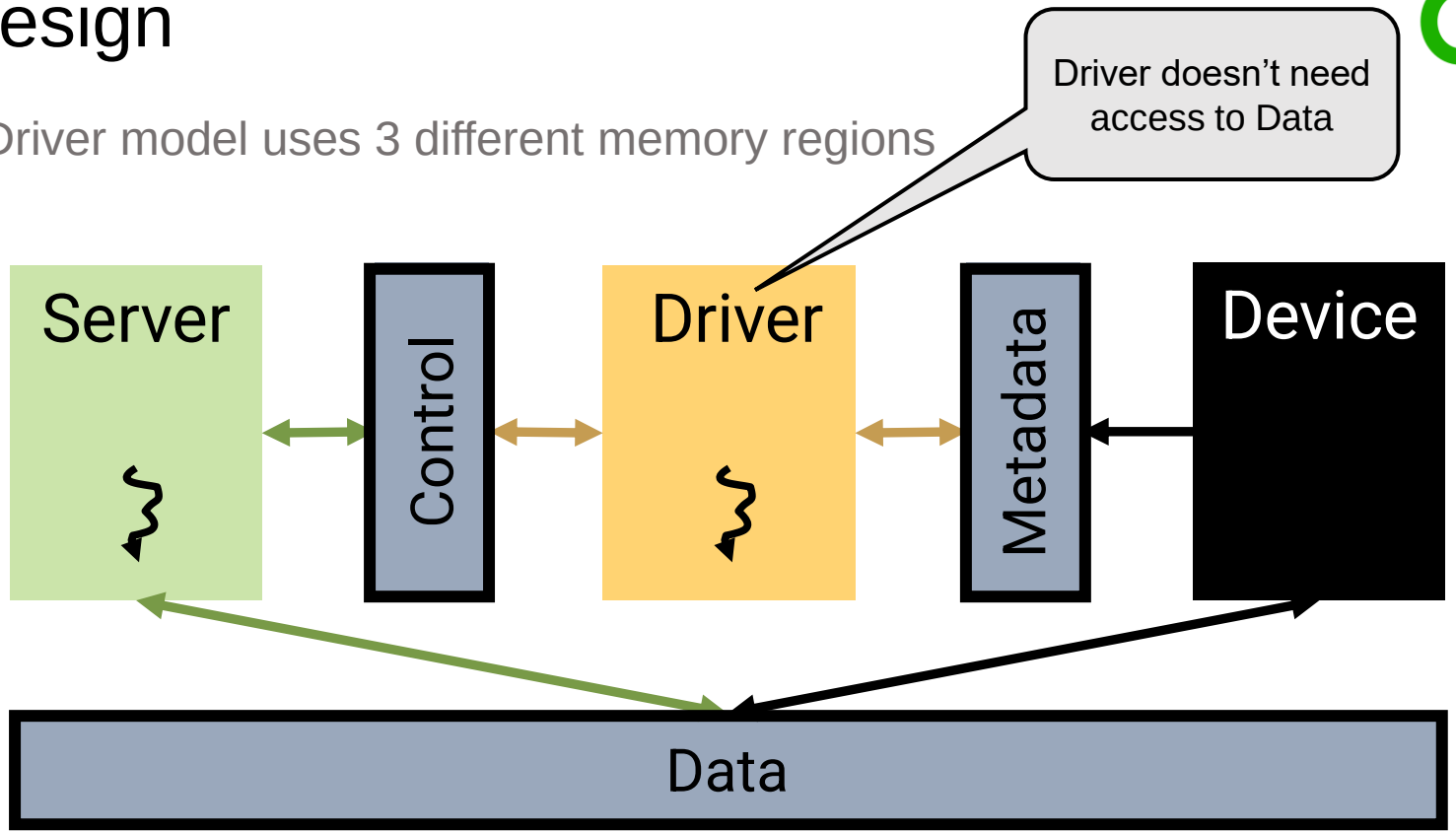
Model for performant device drivers

Asynchronous, zero copy transport layer to provide communication means

- Currently supports networking focused system
- Implemented on top of both CAmkES and seL4 Core Platform

Design

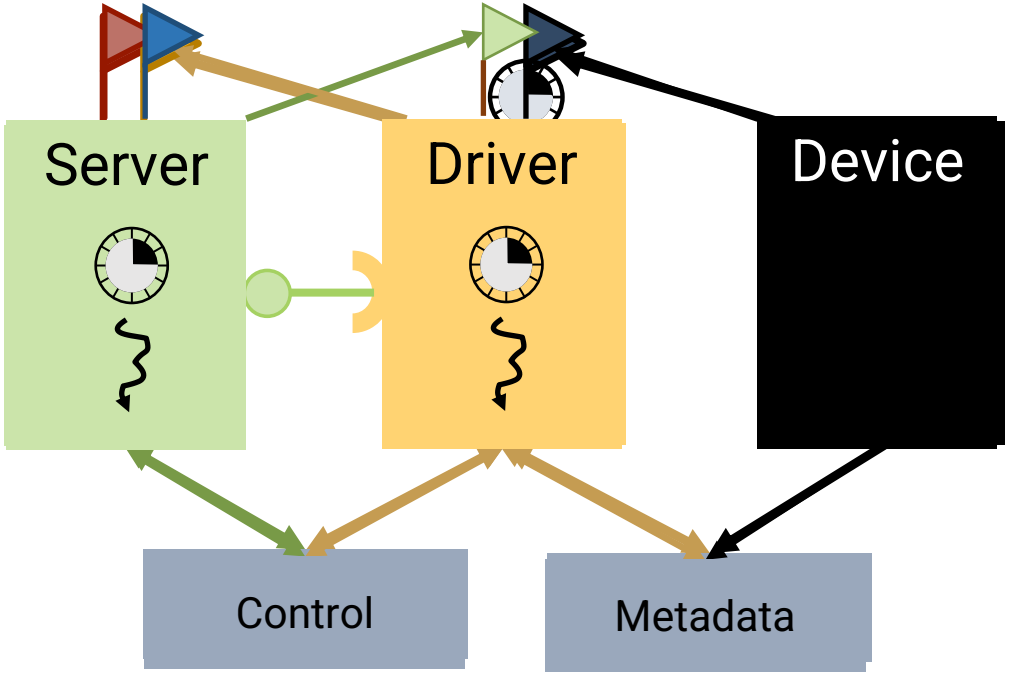
- Driver model uses 3 different memory regions



Driver Model

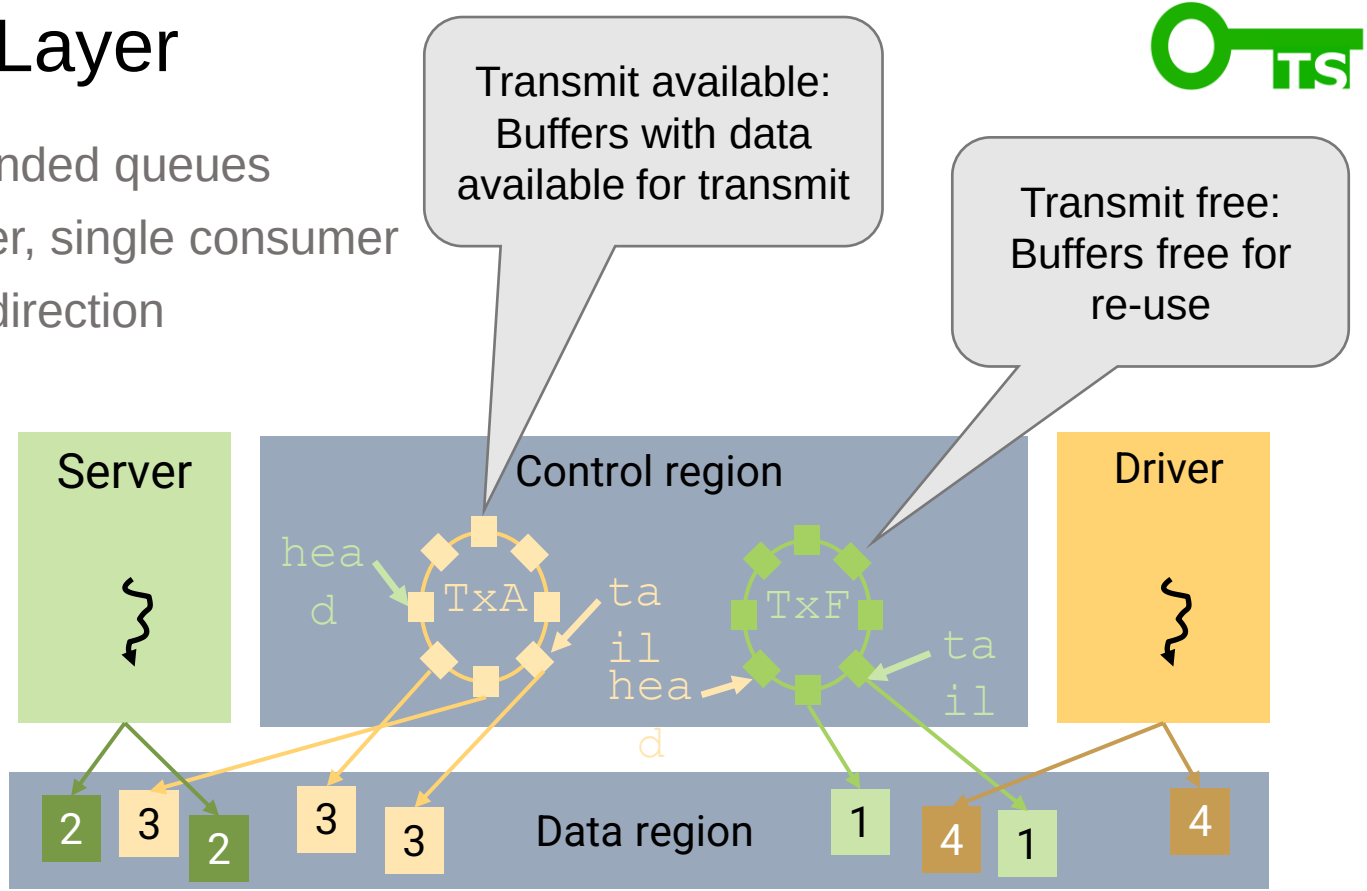
- Purely reactive
- Single threaded
- Simple

- Active
  … or passive?



Transport Layer

- Lock free, bounded queues
- Single producer, single consumer
- 2 queues per direction
- Zero copy



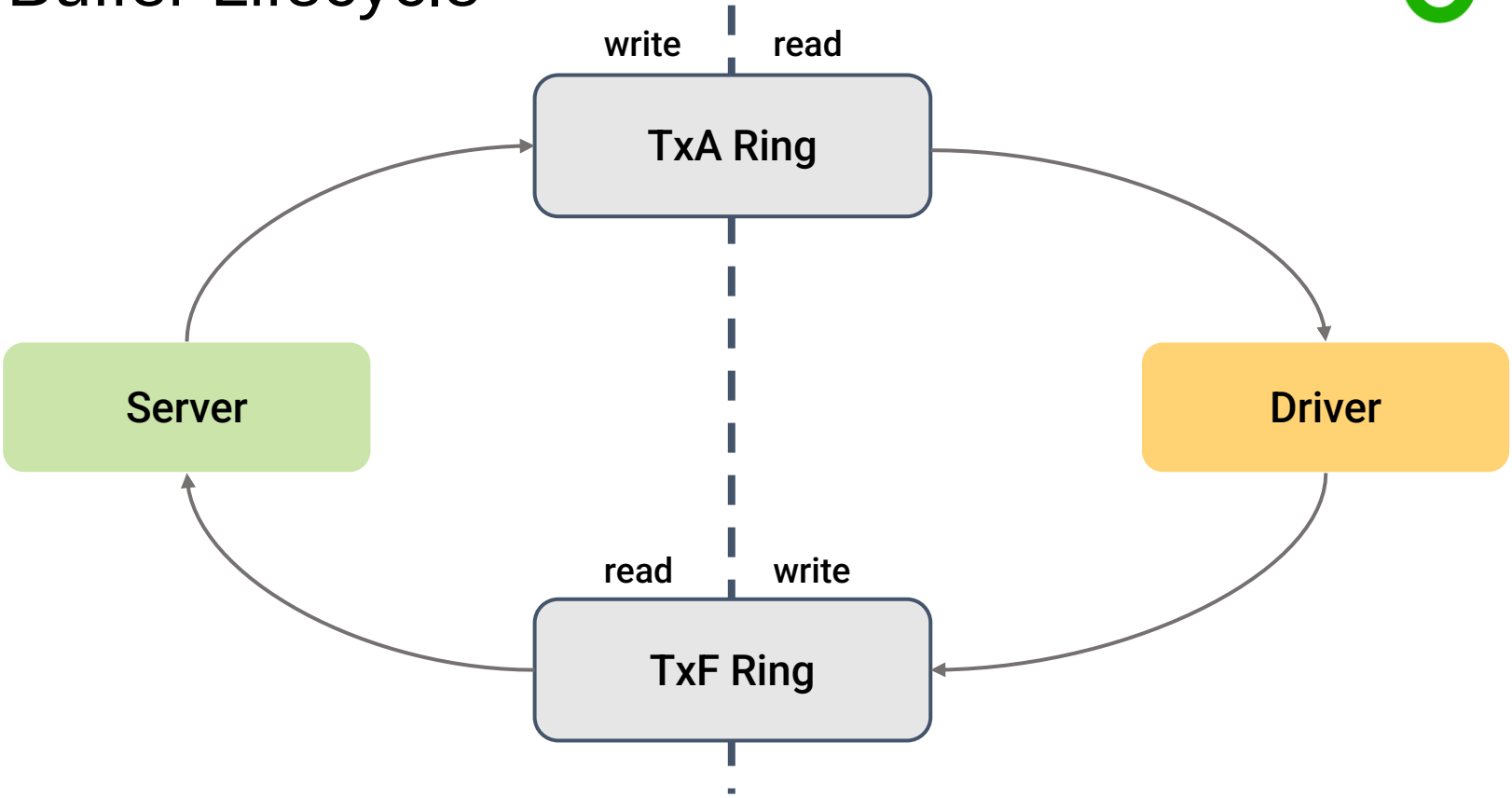
Transport Layer

```
struct buffer_descr {
  void *address;
  size_t length;
}

struct ring_buffer {
  uint32_t head;
  uint32_t tail;
  struct buffer_descr buffer[RING_SIZE];
}
```

```
void enqueue(struct buffer_descr *buffer,
             struct ring_buffer *ring) {
   assert(!full(ring));
   ring->buffer[ring->head % RING_SIZE] = *buffer;
   barrier();
   ring->head += 1;
}

struct buffer_desc* dequeue(struct ring_buffer *ring) {
  assert( !empty(ring) );
  struct buffer_descr *buf = \
           ring->buffer[ring->tail % RING_SIZE];
  barrier();
  ring->tail += 1;
}
```

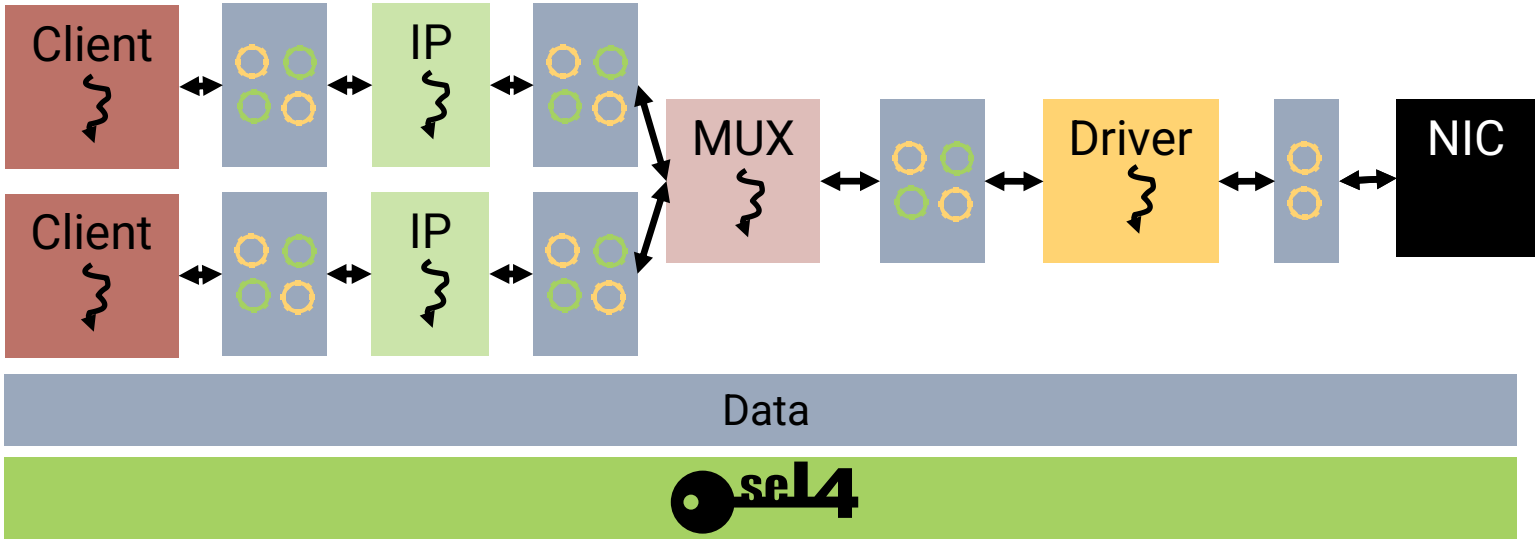
Barrier ensures no writes are re-ordered by the compiler or processor across this point

Buffer Lifecycle



Transport Architecture Scales

- Components can run on separate cores
- Only MUX and driver are trusted.



Driver Code: Active Model

Combine syscalls for performance

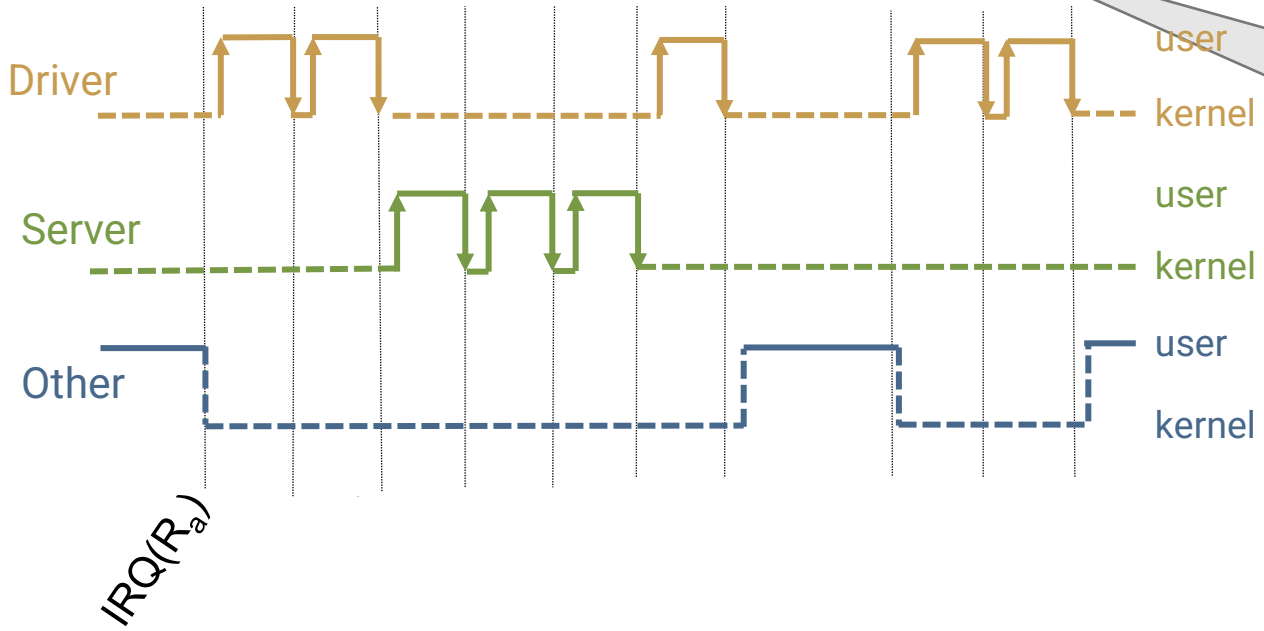
Can process multiple IRQ events in one invocation

Process multiple packets in one invocation

```
main()
   init();
   notif = NULL;
   while(true)
      event = Signal_and_Wait(notif);
      notif = NULL;
      if (event & IRQ)
         handle_irq();
         notif = ack;
         continue;
      if (event & Transmit)
         /* process output */
         while (!full(HW_Tx) && buf = dequeue(TxA))
            enqueue(buf, HW_Tx);
         notif = server;
```

```
handle_irq()
   while (event = clear_hw_events())
      if (event & Tc)
         while (!full(TxF) && buf = dequeue(HW_Tx))
            /* return free Tx buffers to server */
            enqueue(buf, TxF);
      if (event & Ra)
         while (!full(RxA) && buf = dequeue(HW_Rx))
            /* process input */
            enqueue(buf, RxA);
         Signal(server);
         while (!full(HW_Rx) && buf = dequeue(RxF))
            /* return free Rx buffers */
            enqueue(buf, HW_Rx);
```

Kernel Entries: Active Model



6 more than a monolithic kernel requires.

Compare system call cost vs packet processing cost.

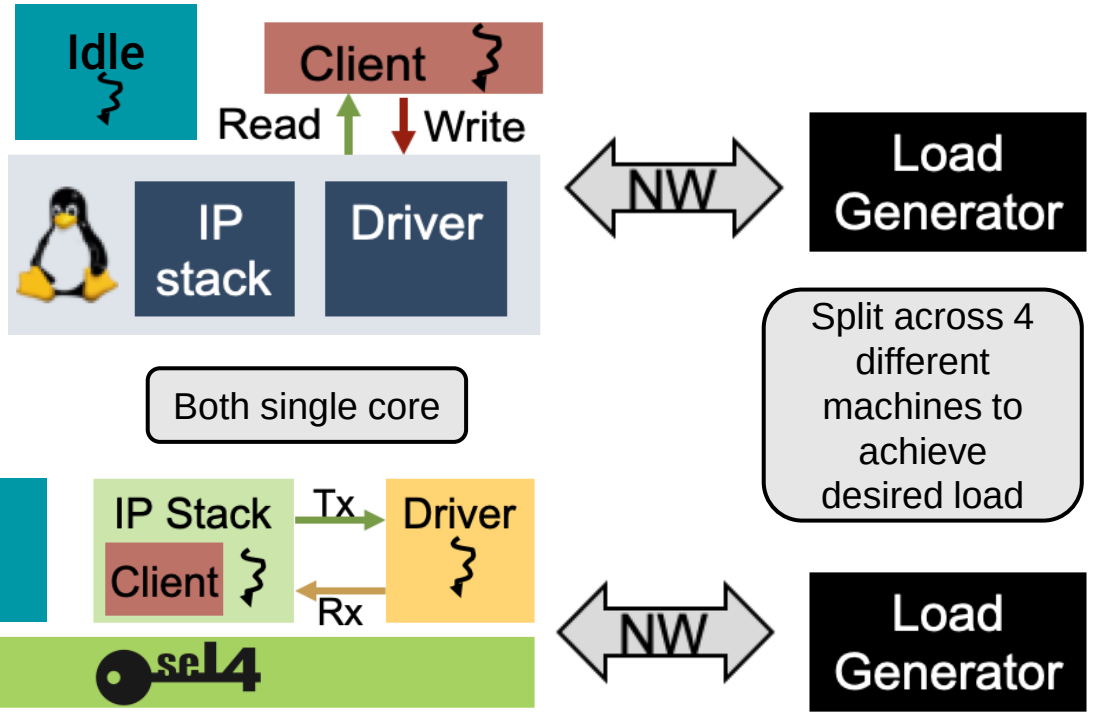
Rate Limiting

- Driver runs at highest priority to minimise round trip times
- Regardless of active/passive model, the protocols for transmit are synchronous.
- Requires limiting CPU time by configuring budgets and periods of scheduling contexts used by higher priority components.
  And/Or limiting the queue size.

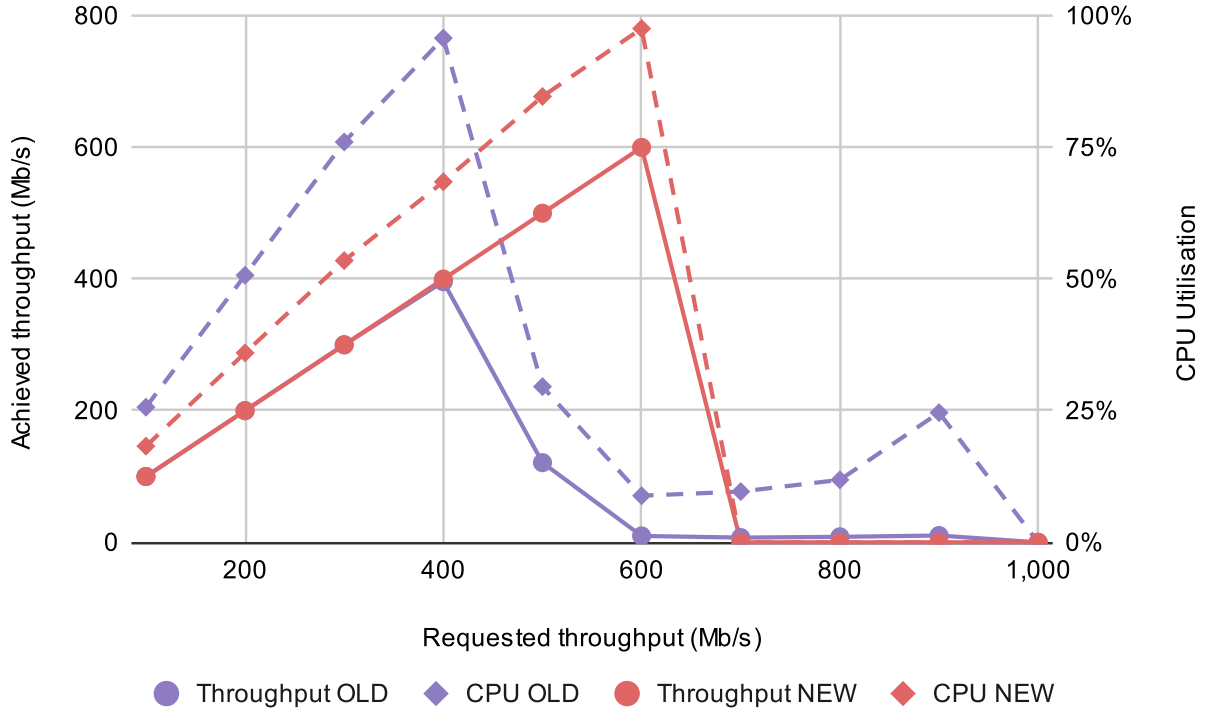
Performance

Set Up

- Client just echoes packets
- IPbench sends UDP packets and measures throughput and latencies
- Idle thread counts cycles to calculate CPU Utilisation



Old Transport vs New: CAmkES Networking Performance

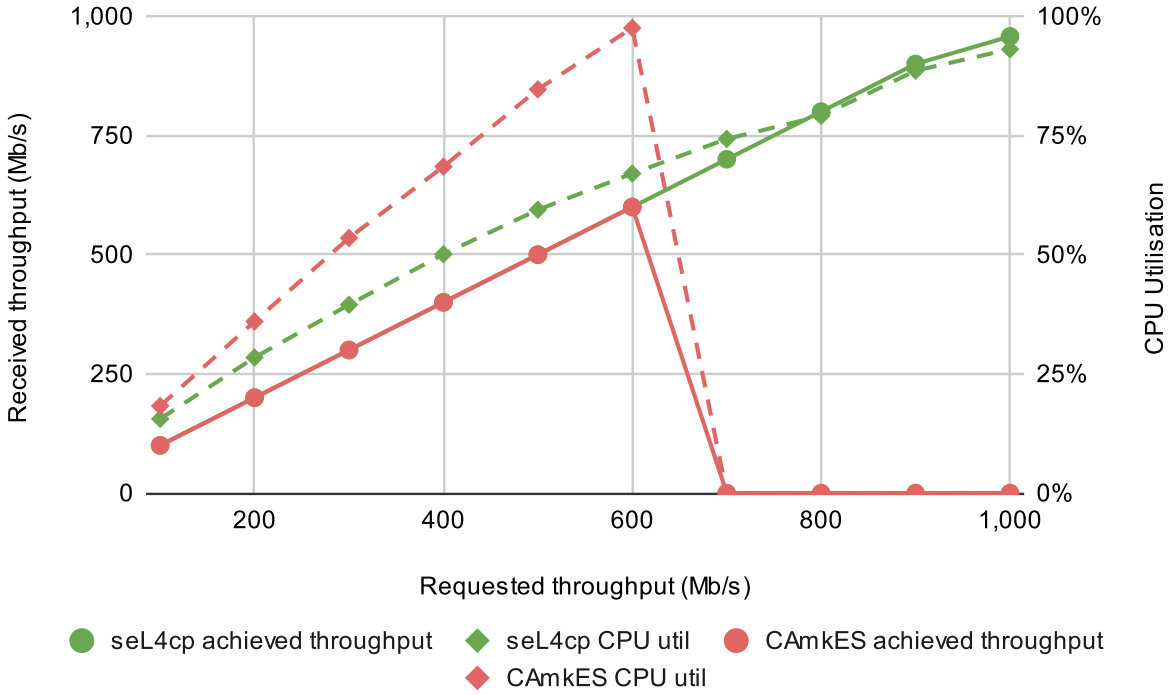


- Simpler transport
- Adjustment of priorities

- Showed 50% improvement!

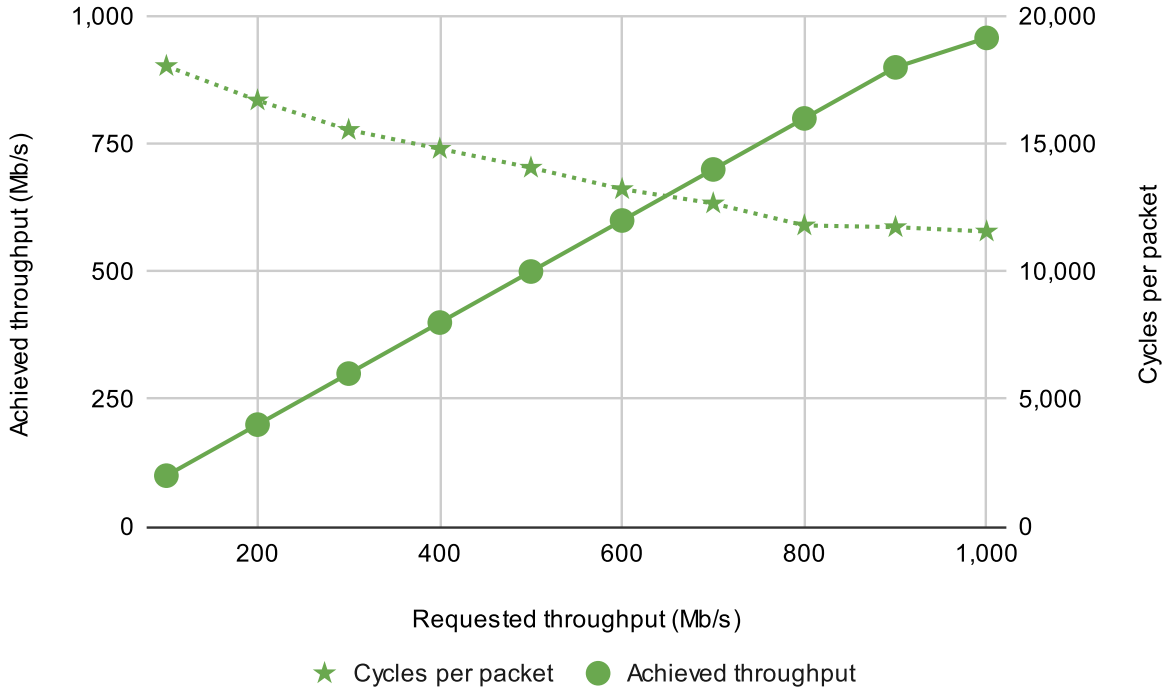
- But could not combine system calls easily…

seL4 Core Platform vs CAmkES Networking Performance

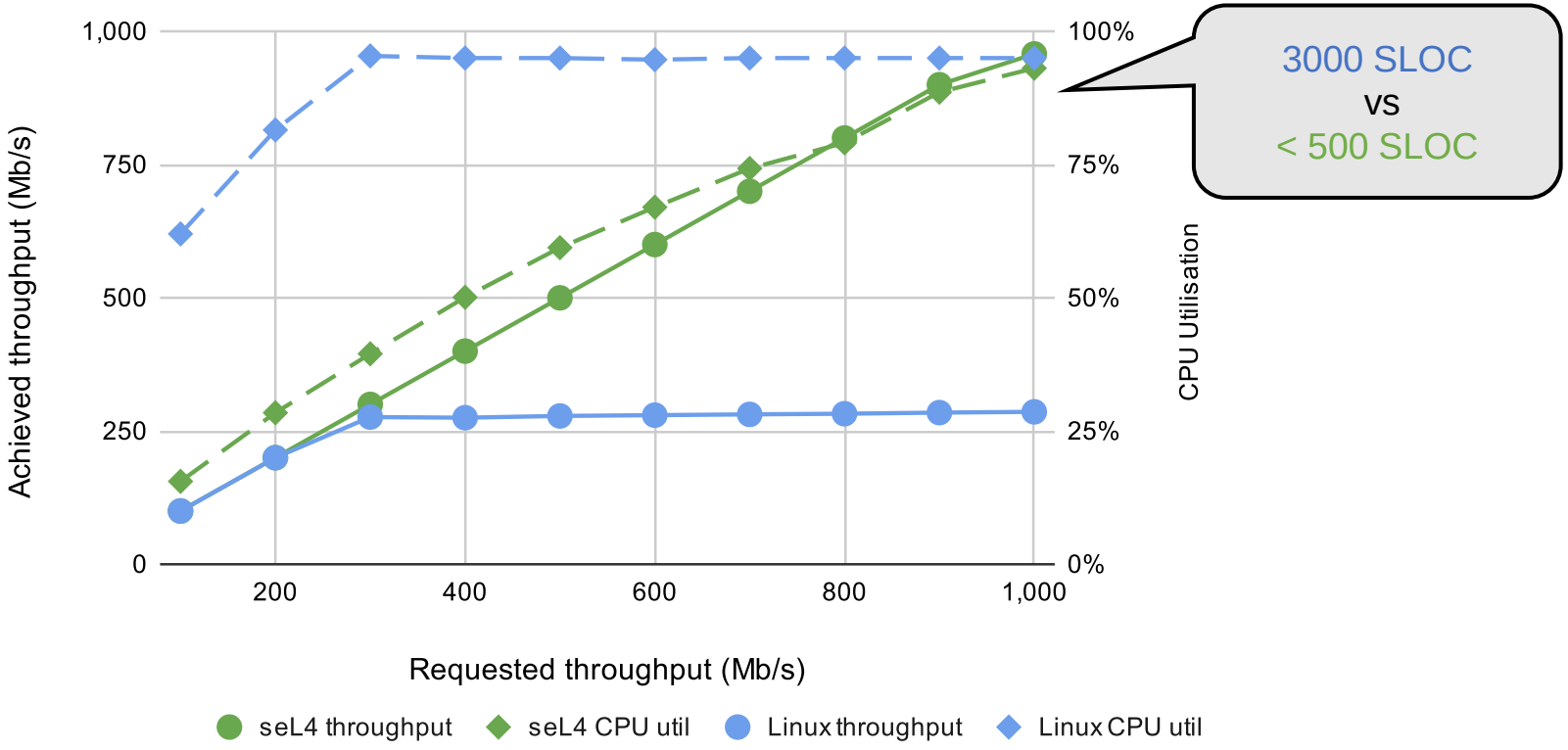


- Reduced kernel entries
- Simpler platform
- Showed 70% improvement, 150% over old CAmkES!
- Limited drivers budget to remove performance collapse.

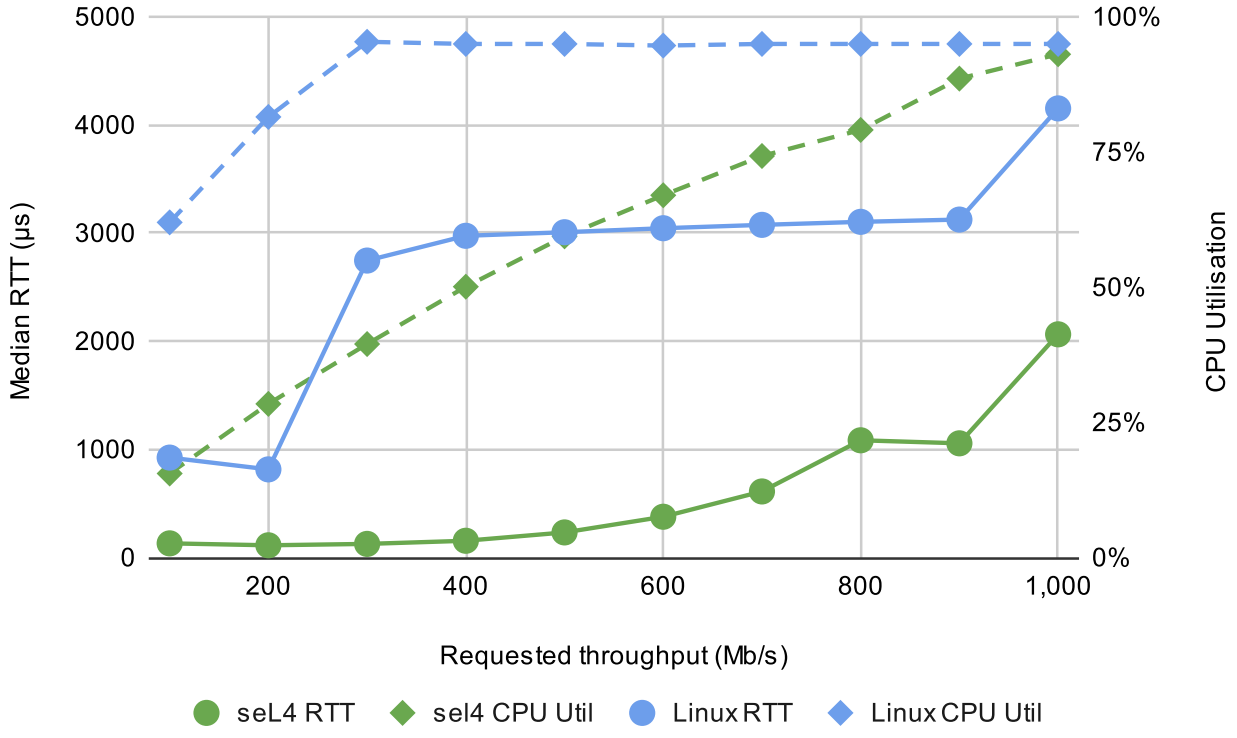
seL4 Packet Processing Cost



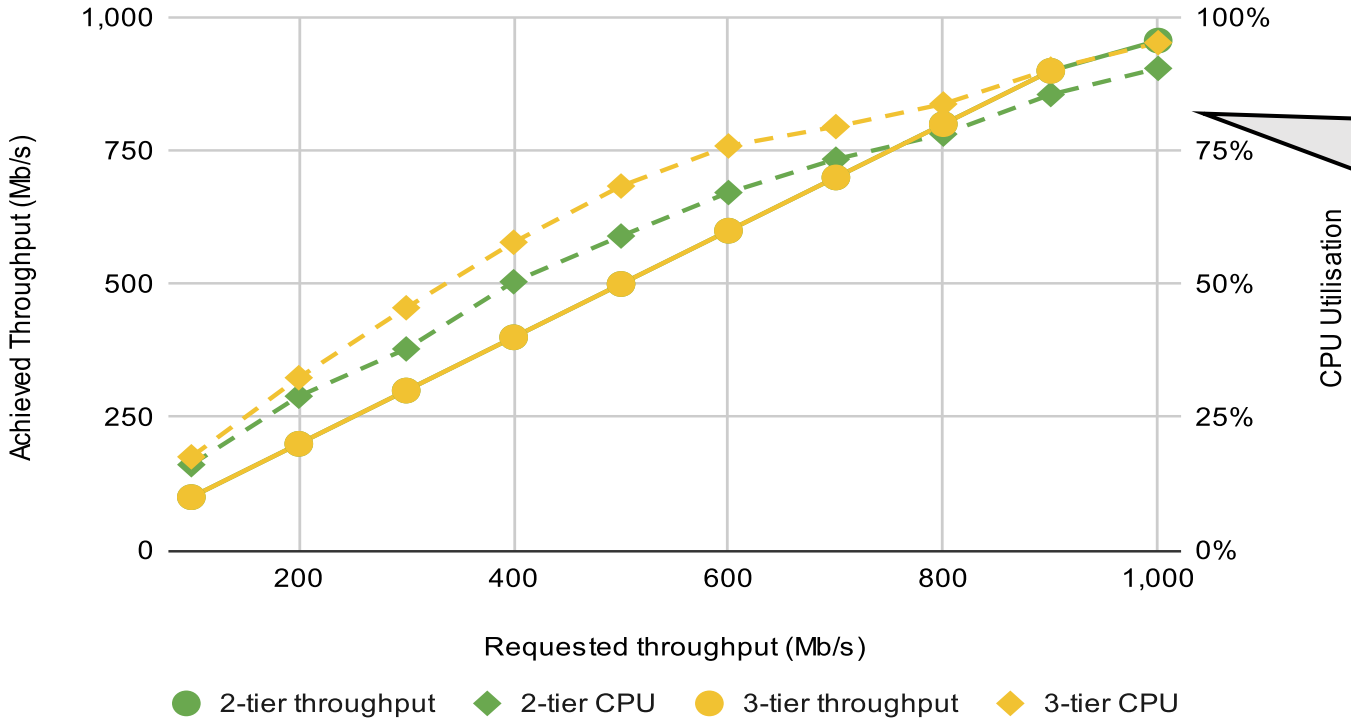
seL4 vs Linux Networking Performance



seL4 vs Linux RTT Comparison



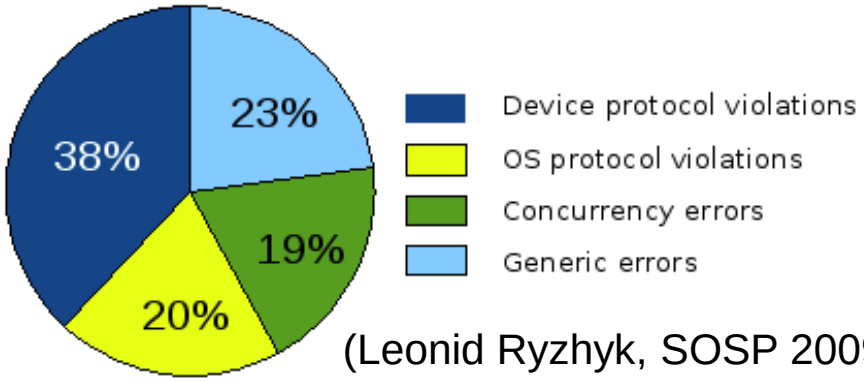
Cost Of A Module Crossing



Only 10% increase… demonstrates scalability!

Takeaways

- Significant performance boost: 150% improvement on old model
- Smaller latencies and higher throughput achieved over Linux
- Simple works!
  Eliminates concurrency bugs
  and will help verification effort.



(Leonid Ryzhyk, SOSP 2009)

Further Work

- Evaluate the passive driver model.
- Benchmark a more complex client.
- Investigate the optimal budgets and periods for different scenarios (eg. Asymmetric traffic).
- Evaluate what an optimised IP stack might look like.
- Design and build a multiplexor.
- Extend the sDDF to support other device classes.
- Evaluate multicore set up.

Code

- Current state of the code as implemented for seL4 Core Platform can be found here: https://github.com/lucypa/sDDF

- RFC: https://sel4.atlassian.net/browse/RFC-12

Questions?

Kernel Entries: Passive Model