Shoot first: Dealing with microsecond latency requirements.

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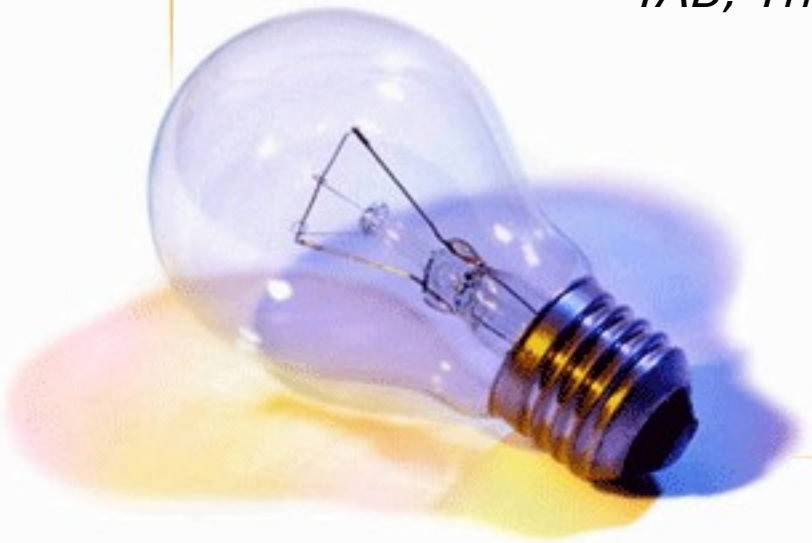


Overview

- Intro
- What is OS noise?
- Typical latencies in the Linux OS
- Noise characteristics
- Shooting first
- Latency troubles
- Solutions (....)
- Conclusion

OS Noise

- Application experiences random delays.
- On the application CPU the following may occur:
  - Scheduling of OS threads
  - Hardware interrupts
  - Faults (page faults?)
  - Timers trigger
  - Scheduler may run other tasks
- Disturbances increase with higher scheduling frequency.
- Lower scheduling frequency makes the delays longer that an application sees.

Time and Space considerations for Latencies

- Latencies are bound with distances due to relativistic speed issues. Nothing violates the speed of light.
- Latencies limit system design and processing speed.
- Signal propagation speeds limit system sizes and create NUMA latency issues.
- Only some latencies can be avoided.
- Bandwidth increases instead of Speed increases.

1 second

- Time needed for a signal to reach the moon.
- Upper bound on any reasonable network latency.
- VM statistics interval in the Linux kernel.
- High performance counters are only guaranteed to be upto date after one second.

100 milliseconds

- A signal can reach all of the earths surface.
- High speed consumer link latency
- Half of TCP retry interval.
- Minimum human reaction speed.
- Frequently used timeout for devices.

10 milliseconds

- 2000 km distance. Signal can reach surrounding metropolitan area.
- Timer interrupt for systems with 100HZ.
- Major page fault (page read in from disk)
- Time interval for a process to receive another time slice if another process has to be run first.

1 milisecond

- 200km distance. Systems in your city.
- Sound travels 34 centimeters. Sound from the speakers reach your ear.
- Seek time of harddisks.
- Max camera shutter speed.

100 microseconds

- 20km. Signal confined to LAN or building.
- Maximum tolerable interrupt hold off.
- Ethernet ping pong times in a LAN via 1Gb/s networking.

10 microseconds

- 2km. Signal confined to a LAN.
- Relativistic time distortion in GPS
- Minor page fault (Copy on write)
- Duration of timer interrupt
- Duration of hardware interrupt
- Typical IRQ holdoff.
- Duration of system call.
- Context switch.

1 microsecond

- 200m.
- Wire segment delay.
- Signal stays within a system.
- Resolution of gettimeofday() system call.
- PTE miss and reloading of TLB.
- Start of hardware interrupt processing.

100 nanoseconds

- 20m. Within the room.
- Cache miss. Time needed to fetch data from memory.
- TLB miss.

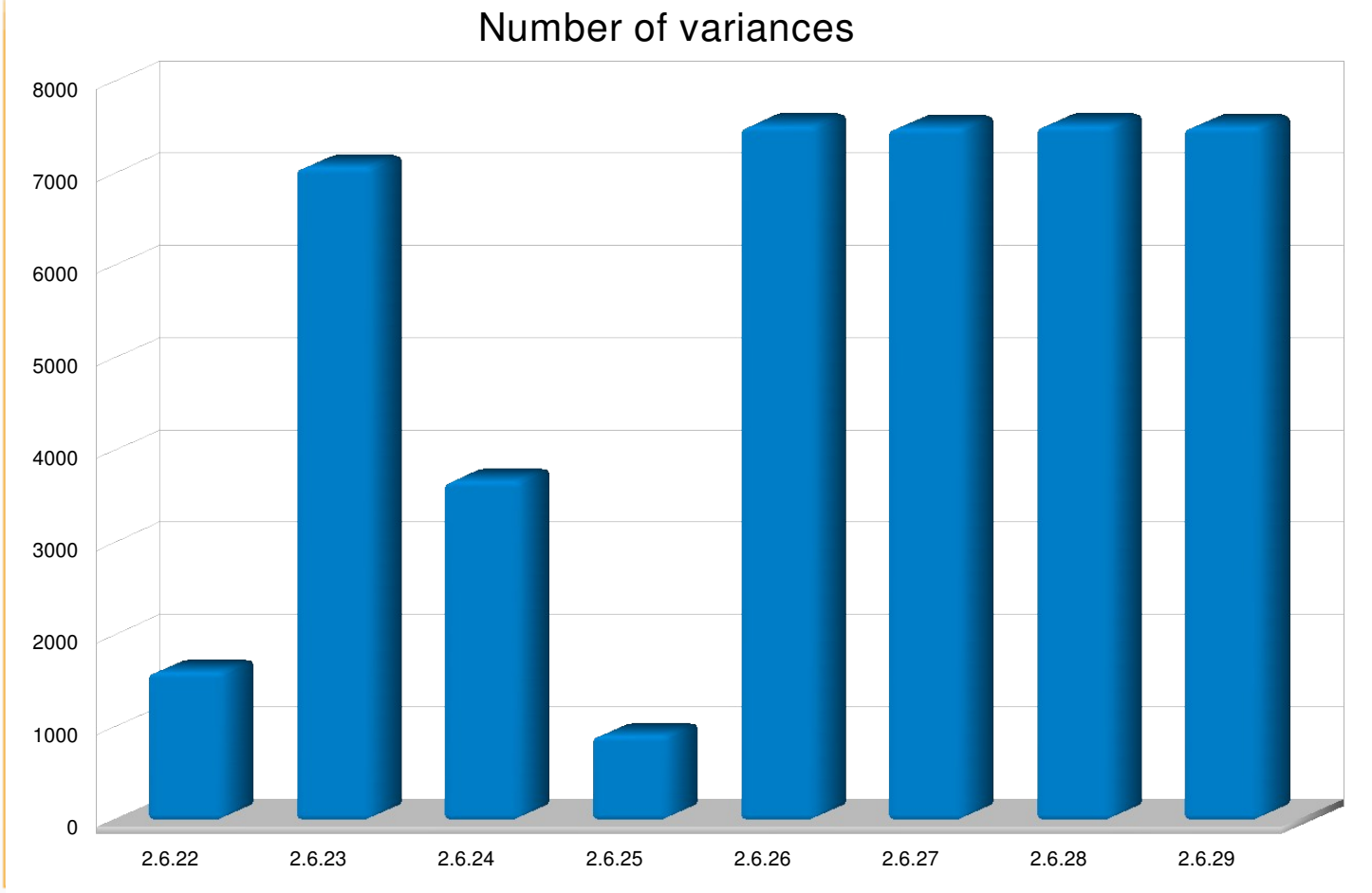
Shot but not dead Or the miraculous resurrection...

- Video gaming across a LAN.
- Two gamers access the same game server.
- Game data propagates according to the distance.
- Gamer with long latency can shoot and the enemy will die on his screen since his system knows the position of the enemy.
- But at the time that the notification of this event reaches the server the other player has already made several other moves.
- So the game server reckons it was a miss and the enemy who just died a horrible death is miraculously resurrected and escapes.

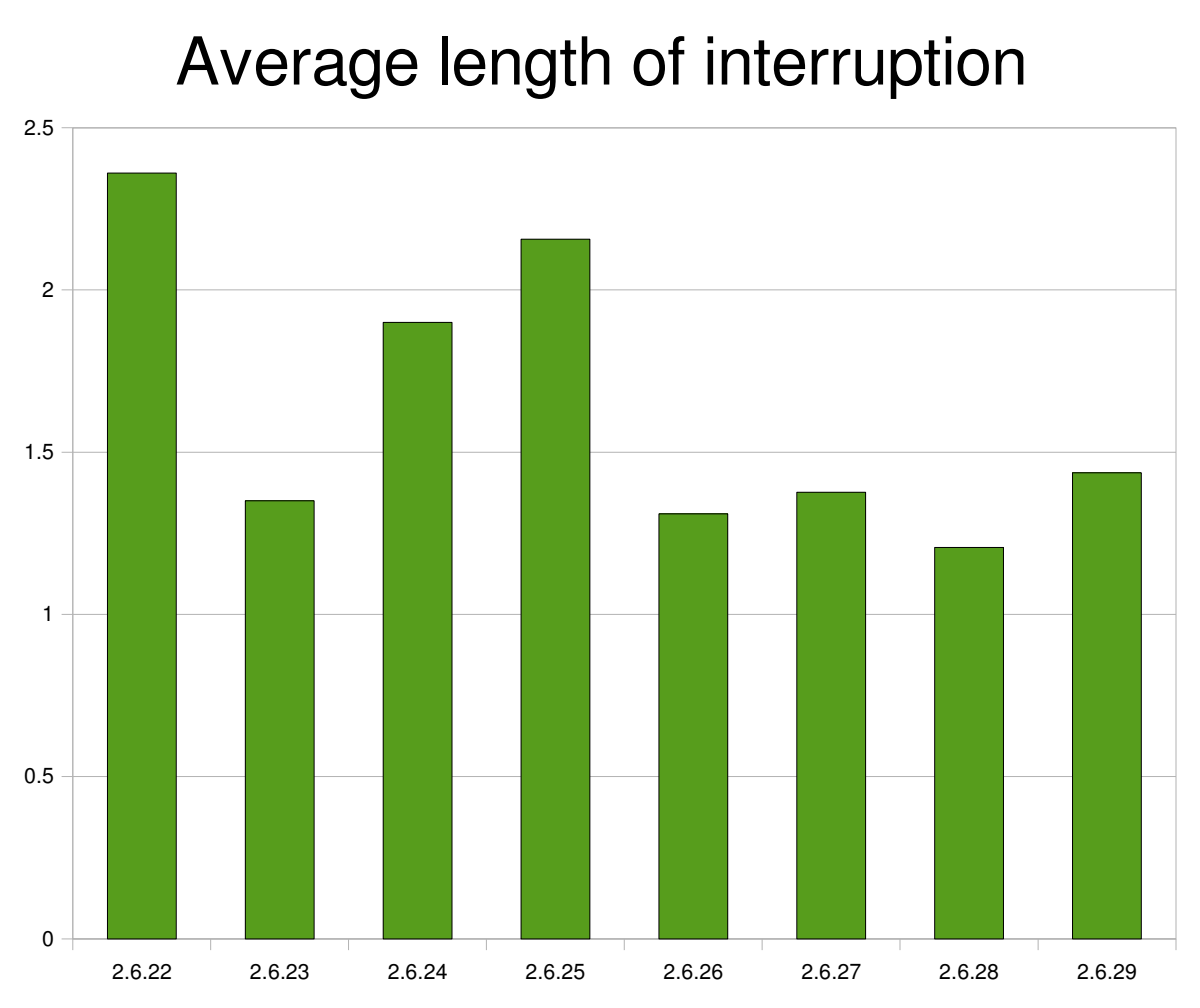
Low Latency tools (gentwo.org/ll)

- **latencytest:** An OS noise measurement tool
  - Number of OS reschedules
  - Number of Faults
  - Holdoffs and their frequency
- **udpping:** Measure minimum communication latencies.
  - Histogram of UDP ping pong traffic
  - Serialized or streaming modes

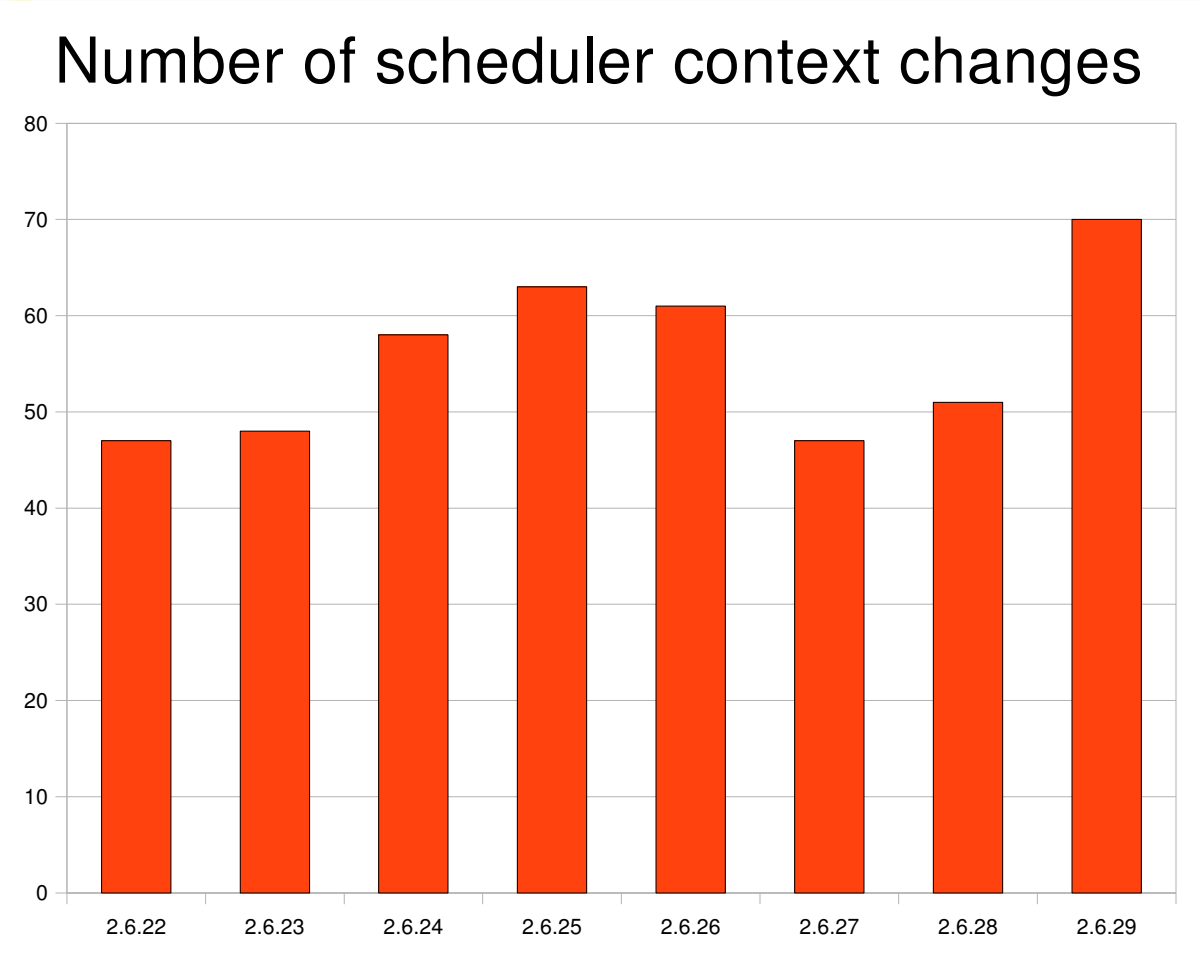
Noise created by the Linux OS



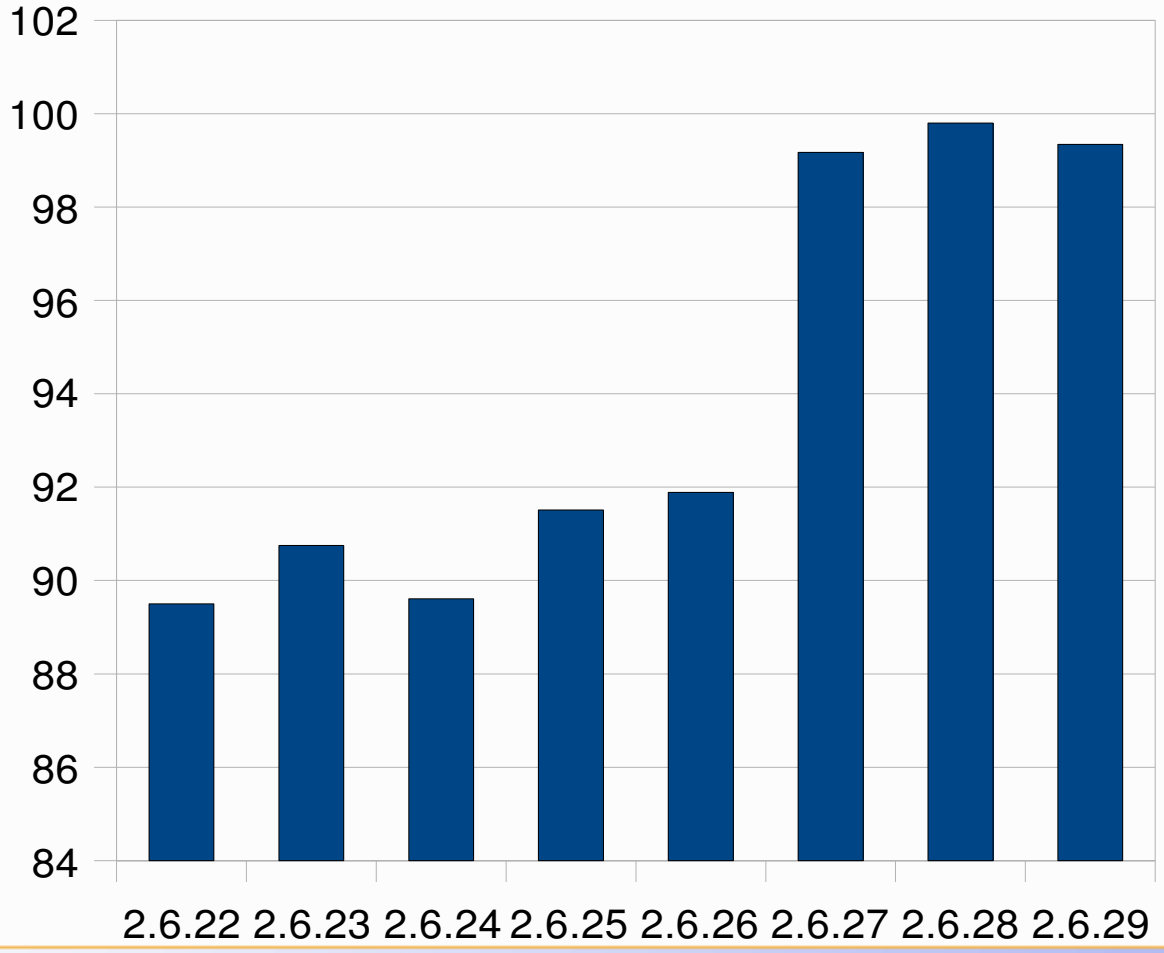
Length of Noise periods (microseconds)



Scheduler interventions



UDP ping pong times (microseconds)



Latency countermeasure

- Prefaulting
- Warming up caches
- Pinning
- Rt priorities
- Thread local variables
- Run old software (RH3, RH4?)
- Restrict OS scheduling to subset of CPUs.

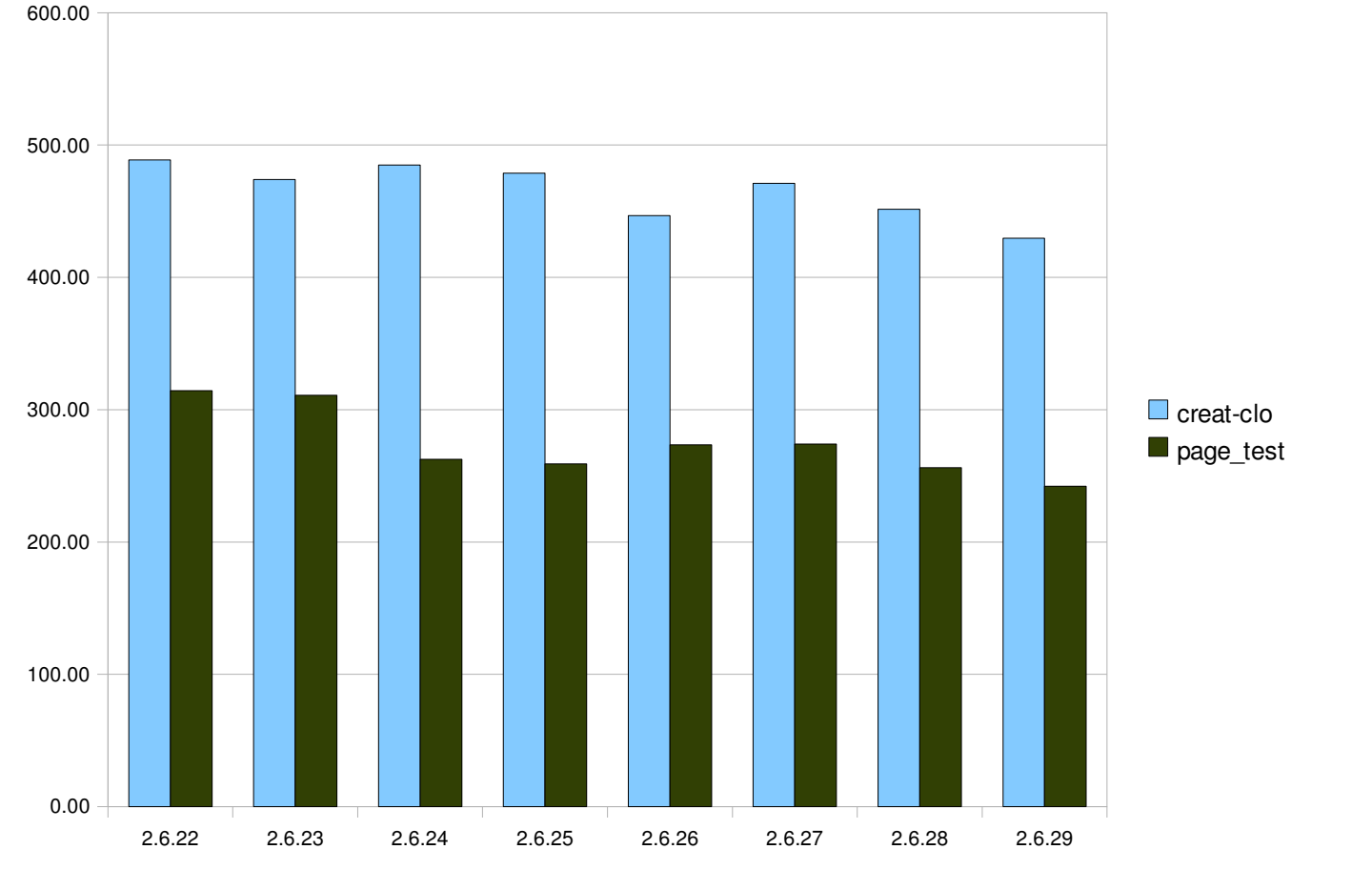
Measures to reduce OS noice

- Process pinning: taskset
- Realtime priorities: chrt
- Prefaulting pages
- Cache prepopulation
- OS features off
- Smaller cache footprint
- OS should not defer processing.

OS bypass

- Atomic ops in user space
- Polling instead of sleeping
- Virtual NIC in user space
- Infiniband RDMA
- Packet MMAPed sockets
- User space RX and TX buffers
- Custom offload libraries

Kernel bloat/AIM9 regressions



Kernel Latency Regressions

- OS use for apps requiring low latency.
- Must use old kernel since newer kernel add bloat and increase latencies.
- HPC, Gaming, financial industry is affected by this in particular.
- Cut off from newer kernel features

Plans to address these

- Advanced features to control affinity of queuing in network stack
- Deadline scheduling algorithm?
- Enable NUMA options?
- Do not schedule on a subset of processors?
- Move noise to a single processor (0)?
- Add more features that require complexity?

Things to do

- Track latencies and kernel performance over long time periods
- Establish better tools to measure OS noise.
- “Its in the noise” is really saying that a change may cause additional latencies.
- Feedback to OS developers re OS noise
- Establish latencies for critical OS paths and benchmark newly released kernels.