NoMali: Understanding the Impact of Software Rendering Using a Stub GPU

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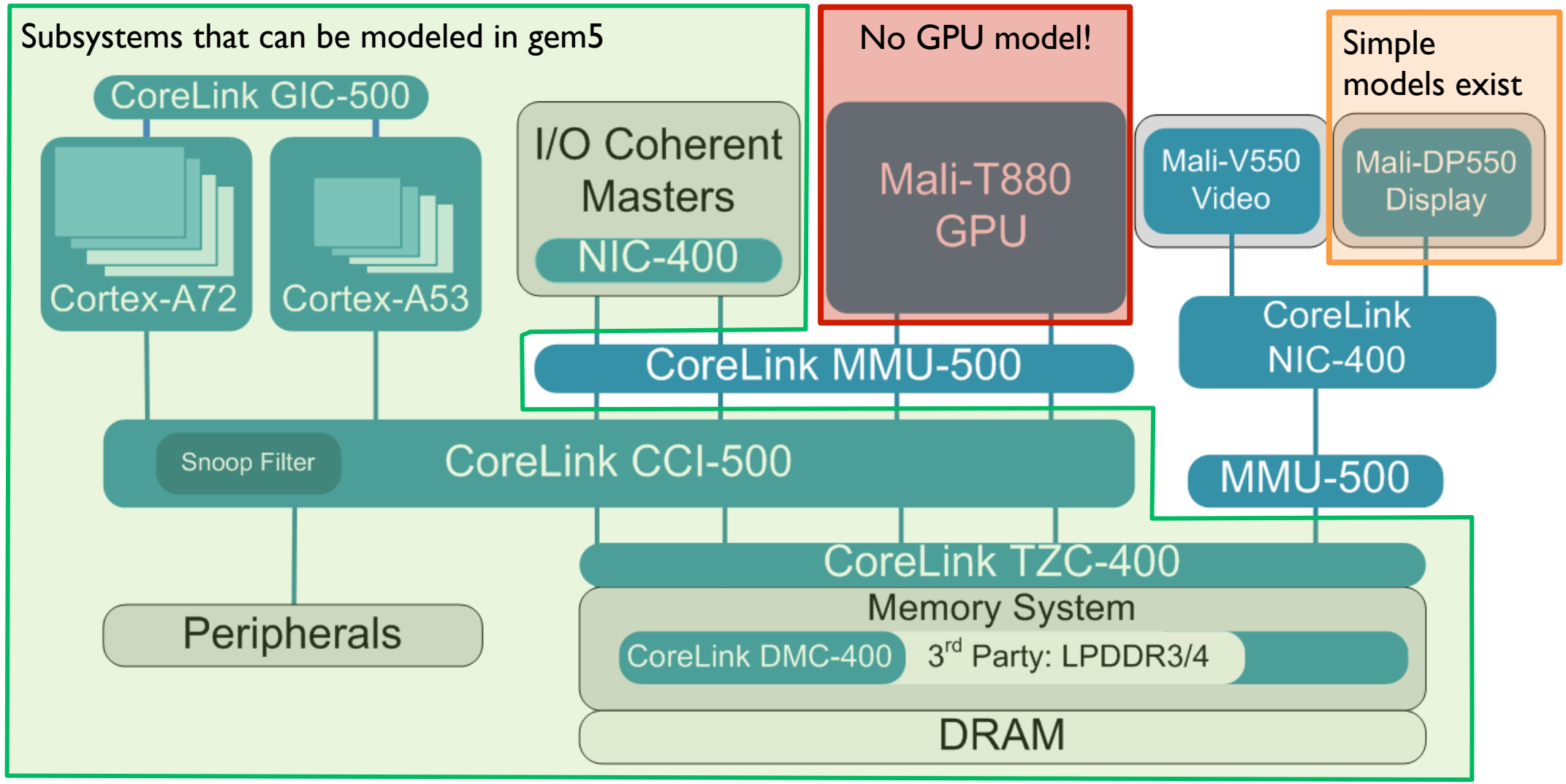
What can be modeled in gem5?



Note: gem5 models the subsystems above, *not* the actual products.

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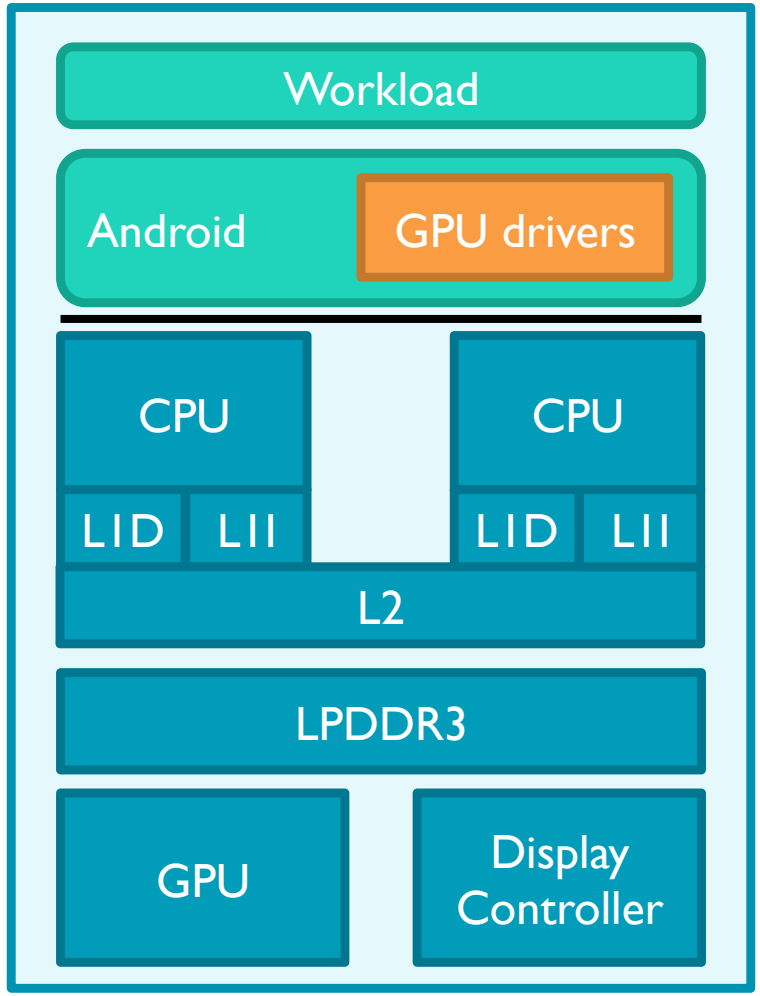
What a real system does



- Modern mobile systems contain a GPU
  - Even watches have GPUs nowadays!
- The GPU is obviously used for 3D
- … but also used for 2D:
  - Composition & alpha blending
  - Rotation & scaling
- Driver stack is complex:
  - Easily 100k+ lines of code
  - Contains an optimizing compiler
  - Can contribute to around 10M instructions/ frame for complex workloads

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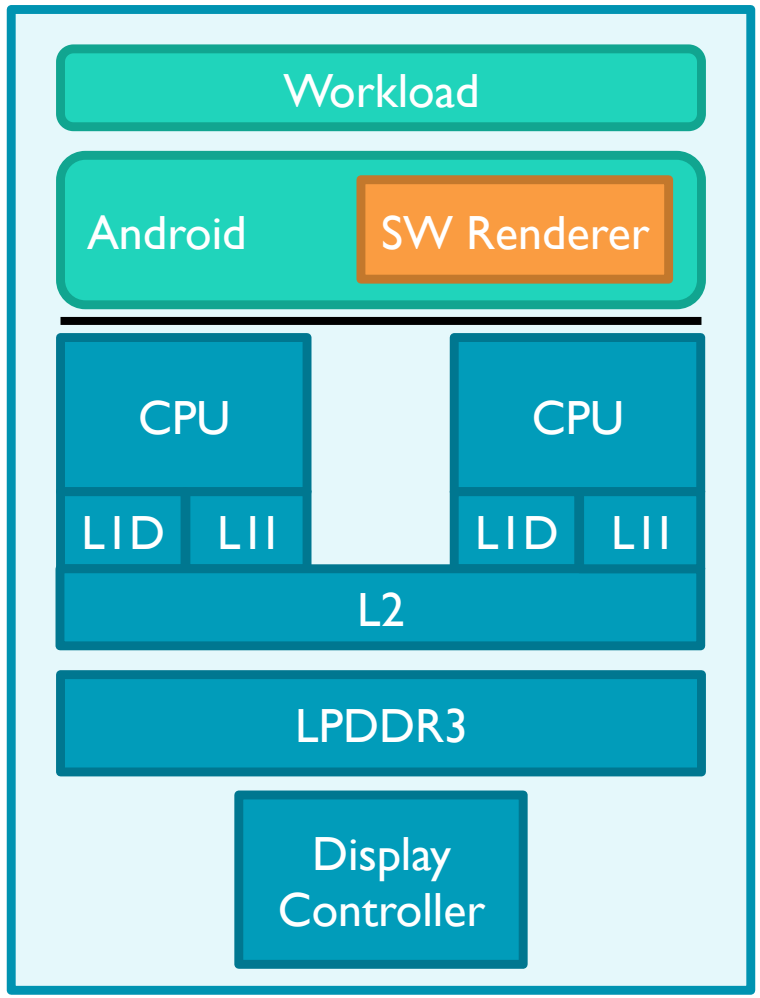
What we normally model



- Software renderer instead of a real GPU
  - Optimization friendly code
  - Can be vectorized
  - Easy-to-predict branches
  - Large memory foot print
- Workload and software renderer compete for resources
  - Can significantly skew core behavior
- Affects 2D applications *and* 3D applications

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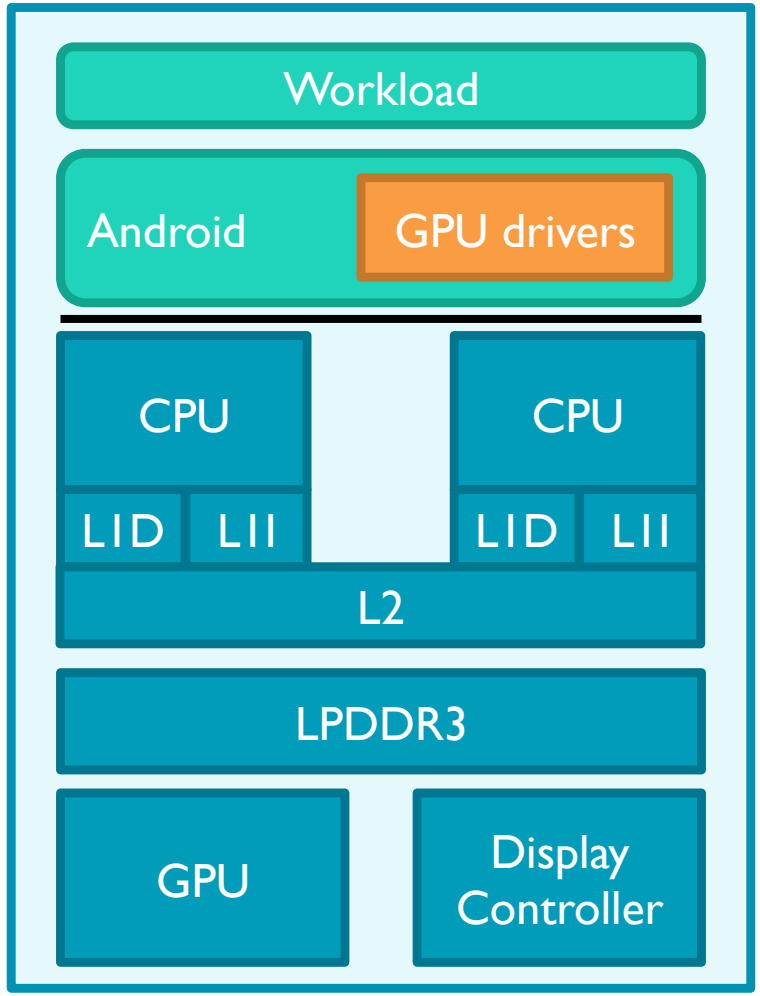
What about simulating the GPU?



- Pros:
  - Golden reference – everything looks like a real system!
  - Captures memory system interactions
  - Graphics output
- Cons:
  - GPU models add a lot of simulation overhead
  - Realistic models not available to the research community
- **Solution:** Don't simulate the GPU!

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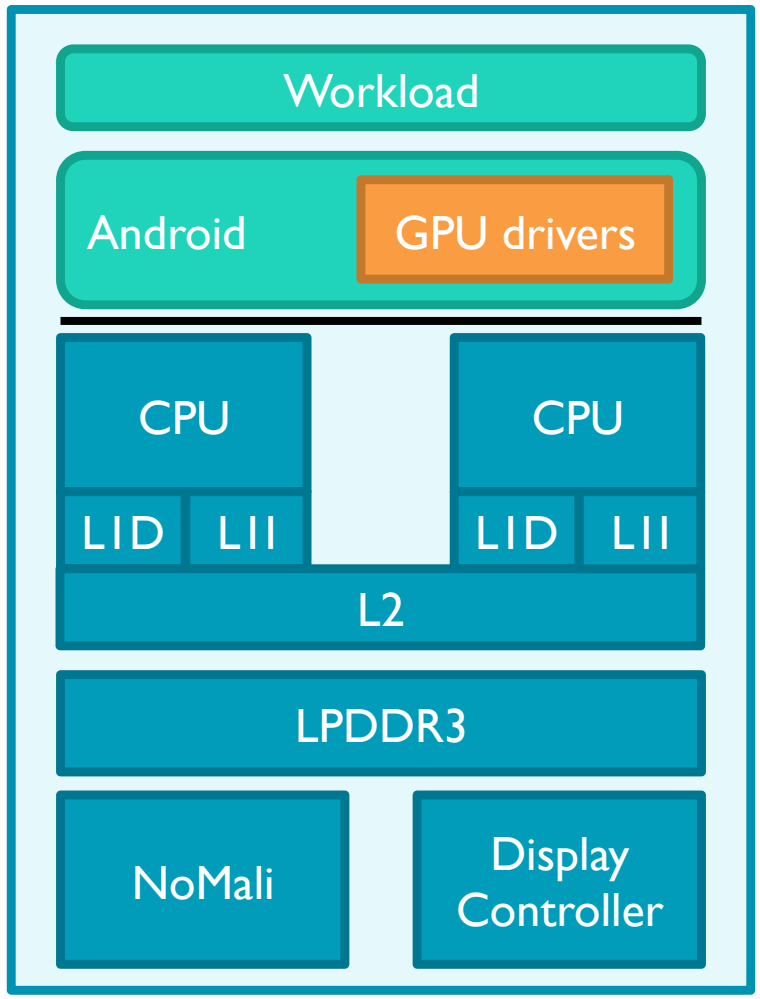
Introducing NoMali



- Looks like a GPU
  - Provides the same register interface
  - Simulates interrupts
- Runs the full driver stack
- Pretends to run rendering jobs
  - Doesn't render anything
  - Signals job completion immediately
- Available to the community
- … but doesn't produce any display output

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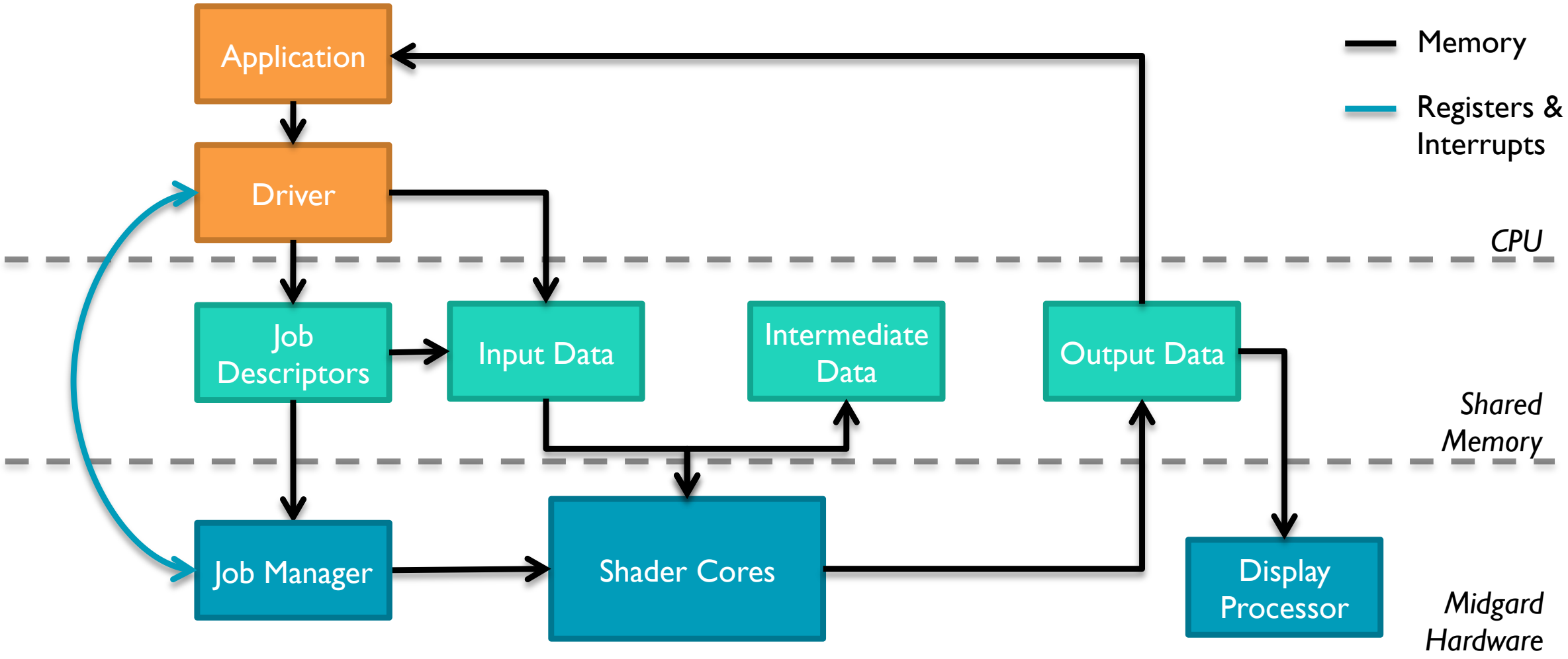
Mali GPU overview



See AnandTech for a good architecture overview

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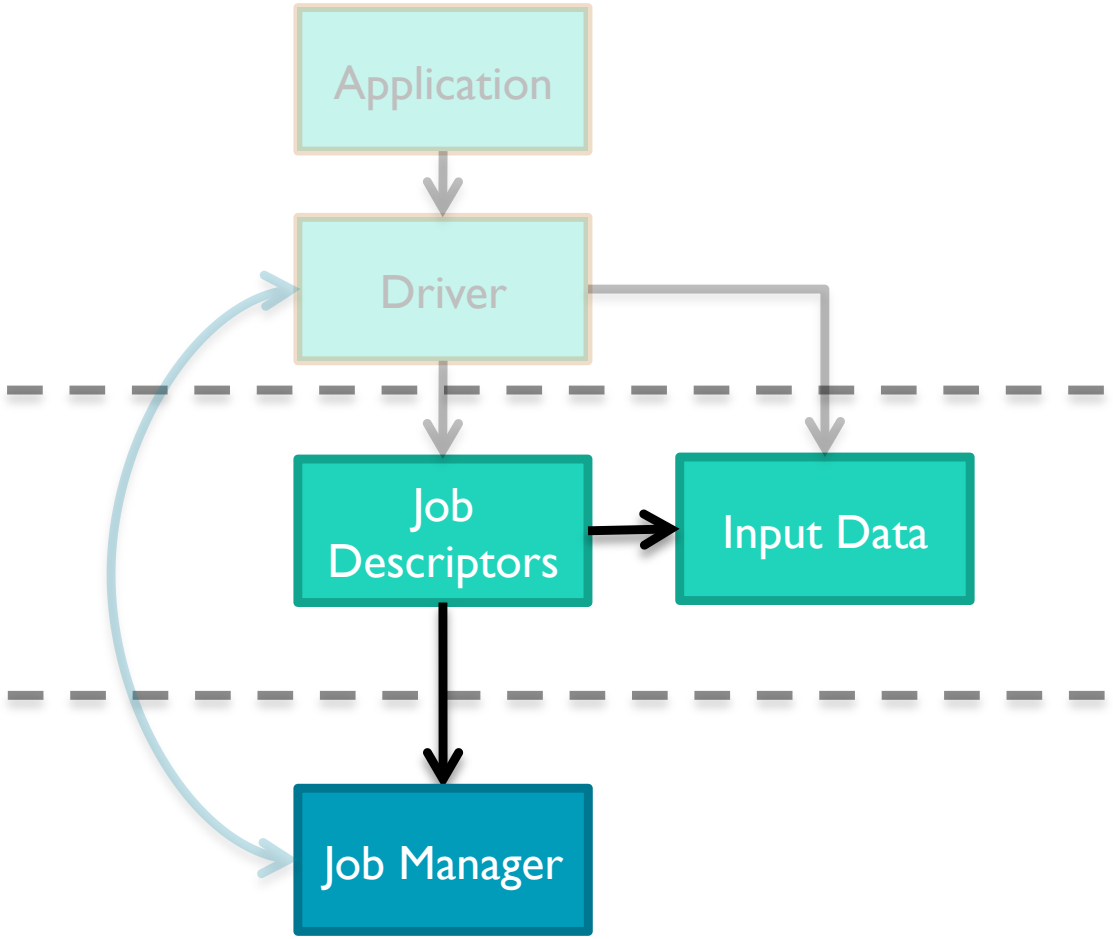
Mali GPU overview: The Job Manager



- Abstracts the underlying μ-architecture
- Controls most aspects of the GPU:
  - Job scheduling
  - Interupts
  - Address translation
  - Caches
  - …
- Job submission through a register interface
  - Job parameters in main memory: Job Descriptor
- Interrupt on job completion

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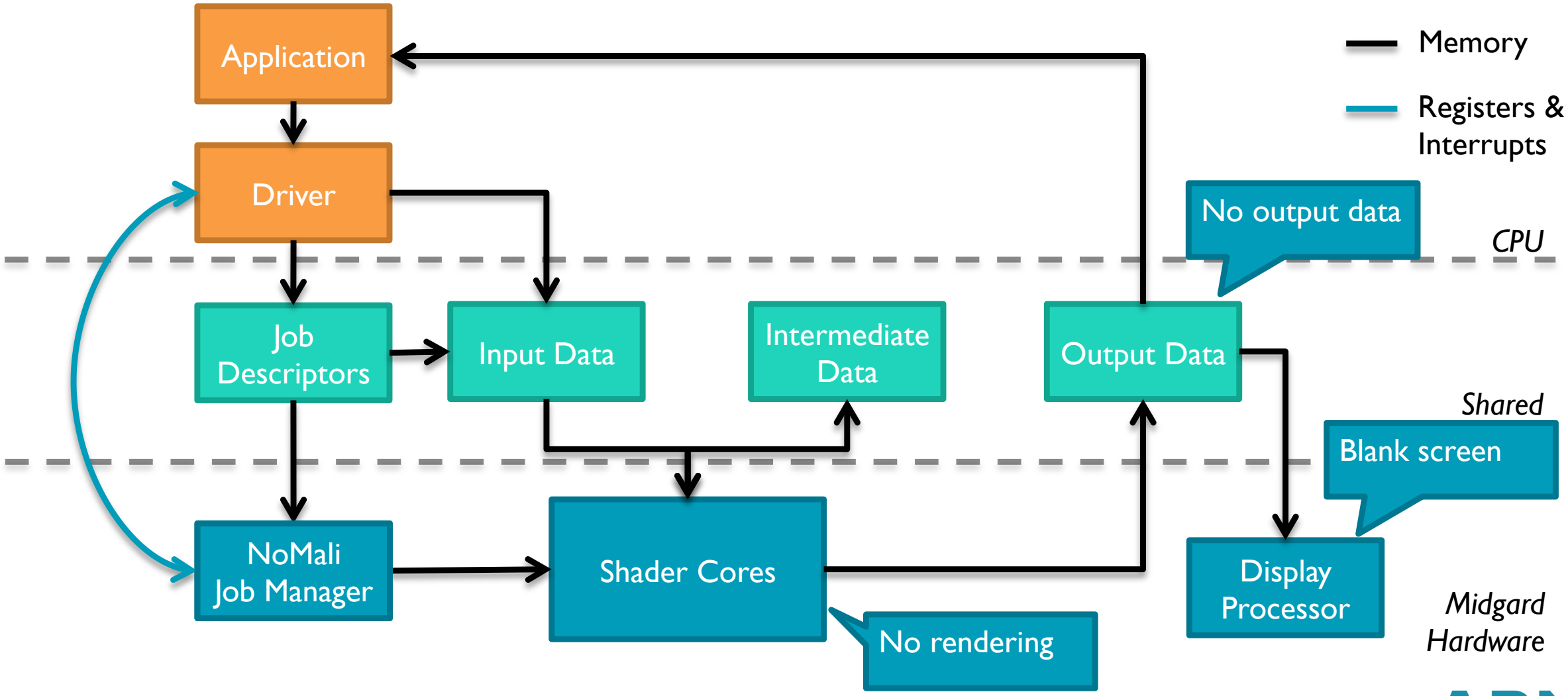
NoMali overview



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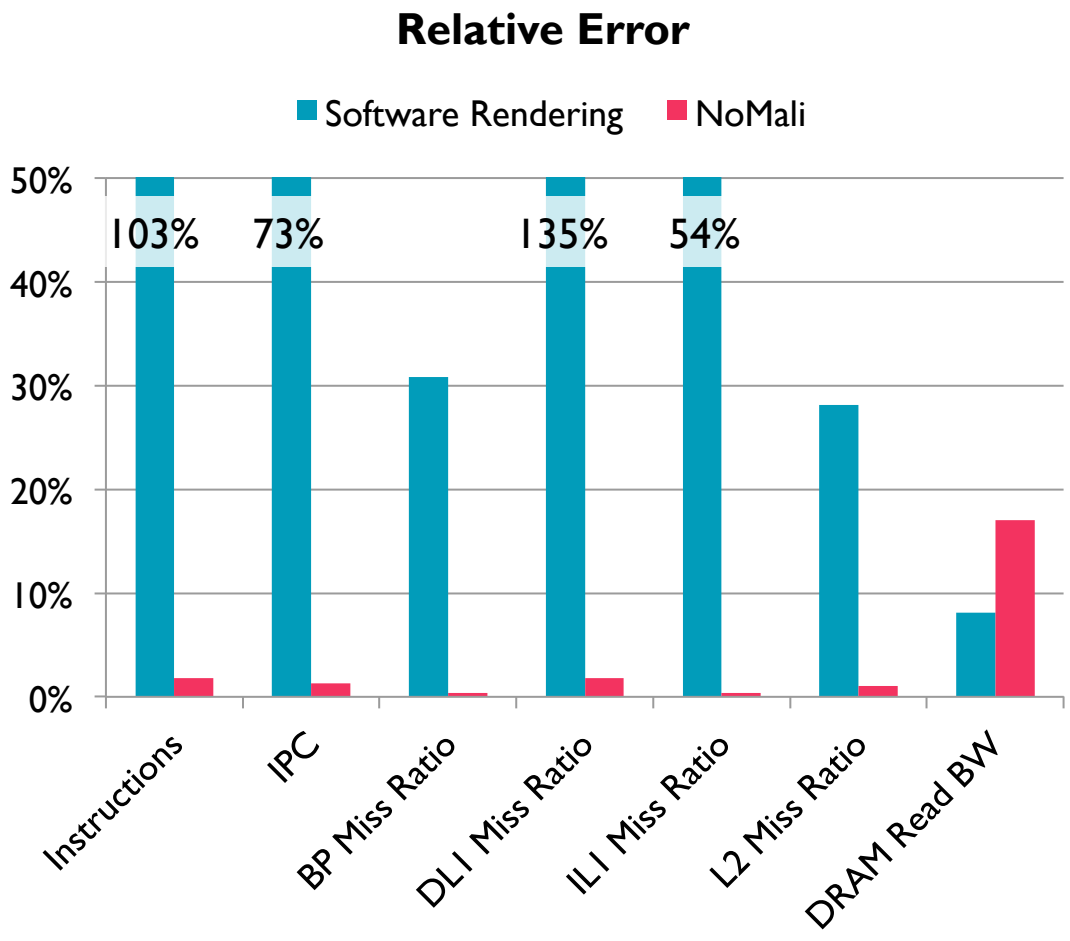
Comparing simulation strategies



- Three experiments:
  - Software rendering, NoMali, GPU reference
- Experimental setup:
  - Android 4.4 (KitKat)
  - BBench
  - Identical disk images in all experiments
- Software rendering results in useless CPU performance
- NoMali is within 2% for CPU performance
  - … and 35% faster!

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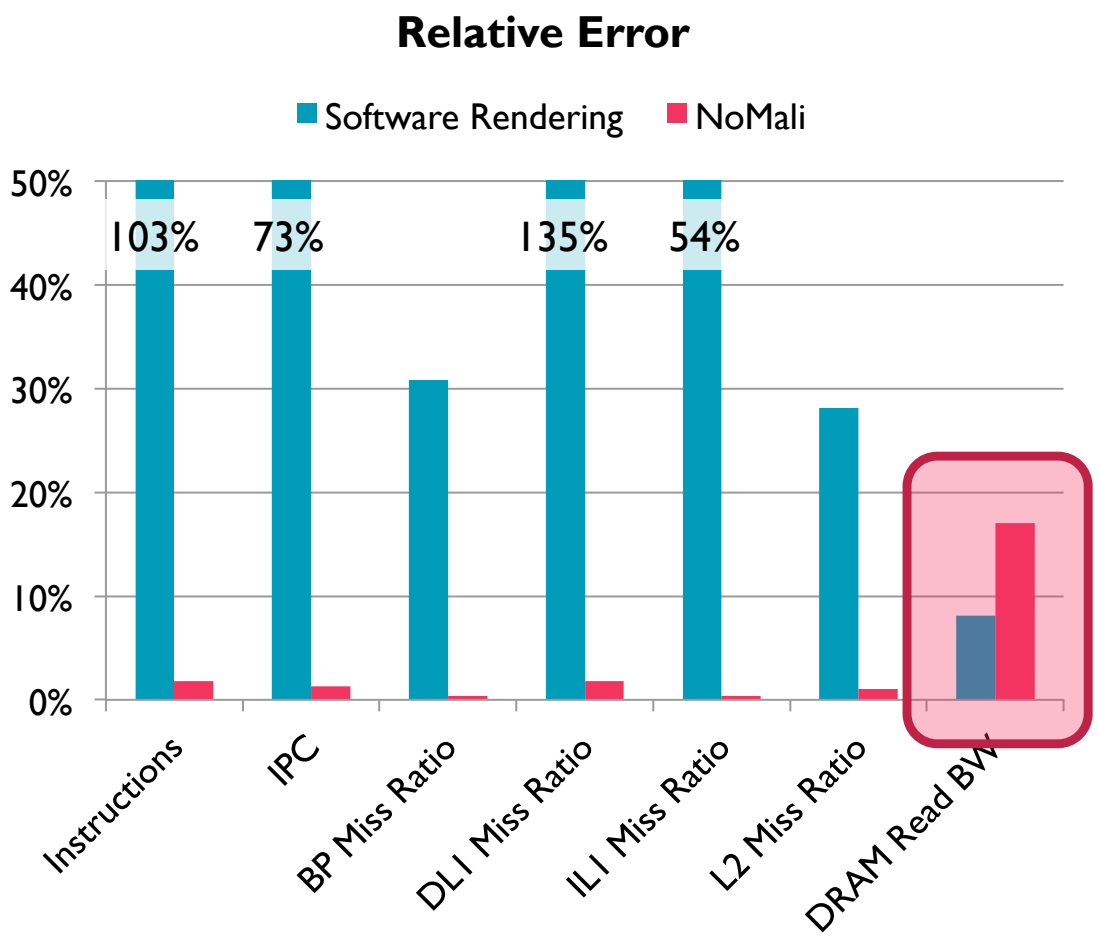
Model limitation: GPU bandwidth



- GPU memory system interactions not simulated
  - Could potentially be faked using traffic generators
- Absolute difference for bbench ~75 MiB/s
  - Not likely to be a problem for CPU-centric studies
- Graphics workloads would experience a larger impact from the GPU
  - NoMali was never intended for that use case.

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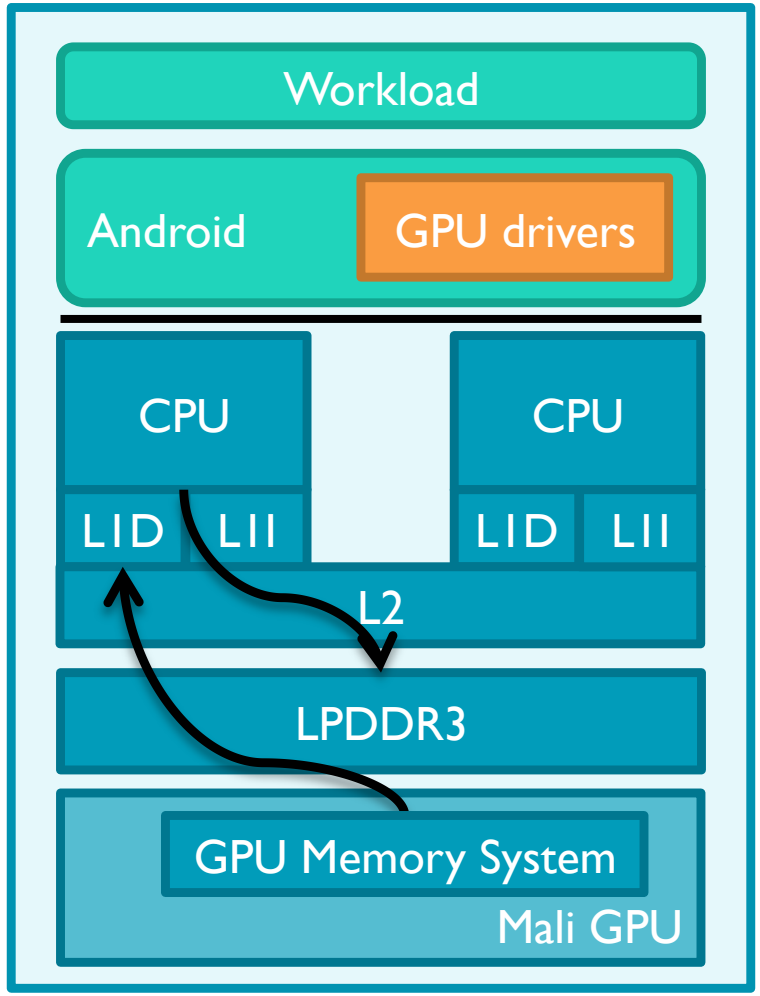
gem5 Issue: inefficient uncacheable memory



- Mali Midgard-series GPUs are IO coherent
  - GPU snoops into CPU caches
  - CPUs can't snoop into the GPU's caches
- The driver disables caching for many regions used by both the GPU and CPU
- Wasn't handled efficiently by gem5
  - Uncacheable accesses were always strictly ordered
  - Resulted in CPIs ~50 (should've been ~2)
  - Fix committed in early May 2015

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gem5 integration plan

- NoMali Model available on GitHub
  - https://github.com/ARM-software/nomali-model
- gem5 integration on Review Board [RB2867, RB2869]
- Requires drivers
  - Will make use of drivers available from MaliDeveloper
  - Requires a recent Android version (KitKat or LolliPop)
- Android KitKat build instructions will be on the Wiki shortly

Questions?