



arm

# Arm Mali GPUs and OpenCL in the mobile and embedded space

Kevin Petit  
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# About me

- + GPU Compute software architect at Arm
  - o Working on Mali GPUs
- + Participating in Khronos working groups since 2016
  - o Mostly OpenCL, SPIR, Vulkan

# A little quizz

- Who has heard of Arm?
- + Who has heard of Arm Mali GPUs?
- + Who has programmed an Arm Mali GPU?

# Mali GPUs

**Arm Mali is the most widely used  
GPU in the world**

\*B\*illions of units!

# Agenda

- + A very brief history of Mali GPUs
- + Introduction to the architecture of Mali GPUs
- + OpenCL in mobile and embedded
- + Some challenges for OpenCL in mobile/embedded space

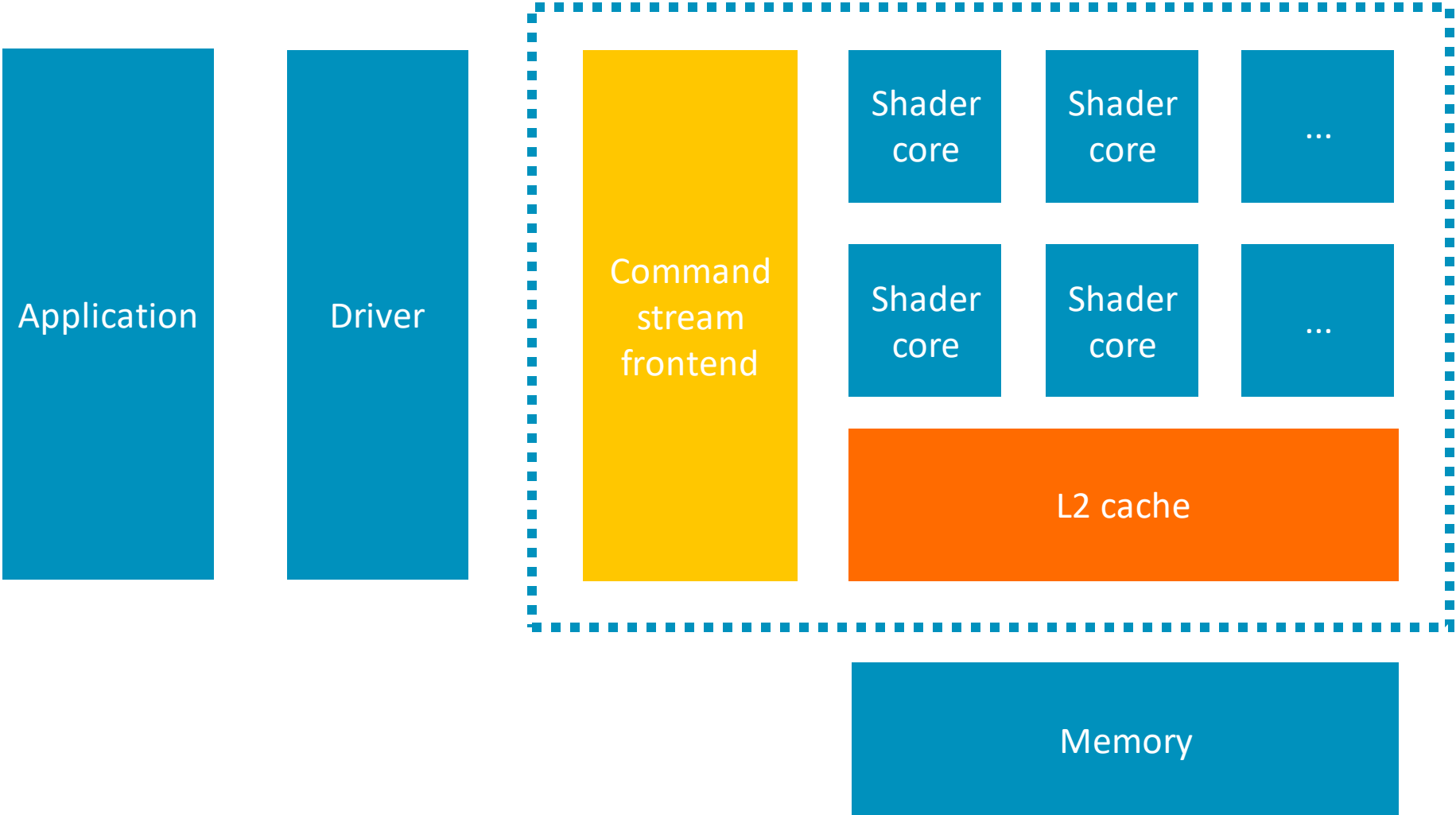
# Mali GPUs – A brief history

- + 2005: Falanx announces Utgard architecture and Mali-200 GPU
- + 2006: Arm acquires Falanx
- + 2010-2014: Midgard architecture
  - o Unified shaders, VLIW engine
  - o <https://www.anandtech.com/show/8234/arms-mali-midgard-architecture-explored>
- + 2016-2018: Bifrost architecture
  - o Warp engine, thread-level parallelism
  - o <https://www.anandtech.com/show/10375/arm-unveils-bifrost-and-mali-g71>
- + 2019 onwards: Valhall architecture
  - o See next slide
- + To learn more
  - o [https://en.wikipedia.org/wiki/Mali\\_\(processor\)](https://en.wikipedia.org/wiki/Mali_(processor))
  - o [https://www.youtube.com/watch?v=DO\\_68Hjs2UI&list=PLKjl7IFAwc4QUTejaX2vplwXstbgf8lk7&index=5](https://www.youtube.com/watch?v=DO_68Hjs2UI&list=PLKjl7IFAwc4QUTejaX2vplwXstbgf8lk7&index=5)

# Mali Valhall 5th gen architecture

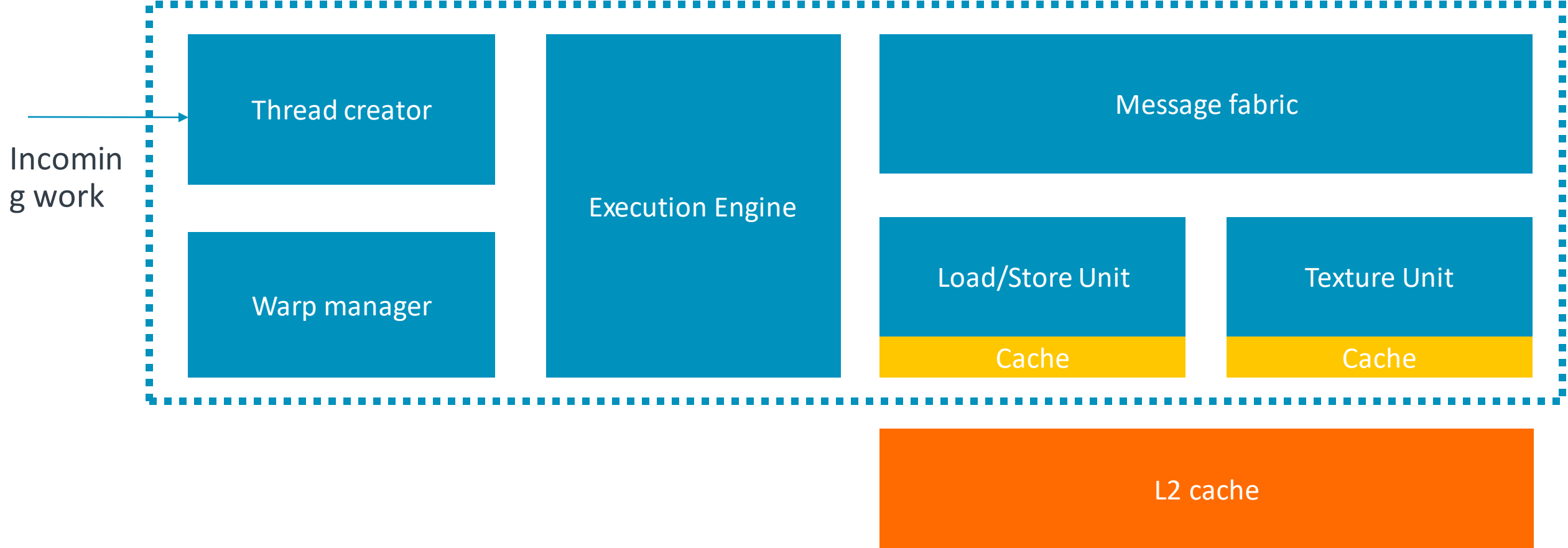
- + Command-stream frontend
  - Flexible, good fit for modern APIs
- + 16-wide warp engine
  - Superscalar, matrix multiplication acceleration, etc
- Compression
  - AFBC, AFRC, etc
- Ray tracing
- ... and a lot more

# Anatomy of a modern Valhall GPU





# Zooming into a shader core



# OpenCL in mobile and embedded

- + People often ask: where/how is OpenCL used in the mobile and embedded space?
- + The short answer: it's everywhere!
- From the phone you take your holiday pictures with
- ... to your electric car
- ... with a detour by your TV and/or set top box
- ... not forgetting your security cameras
- ... who said Machine Learning?
- ... and more!

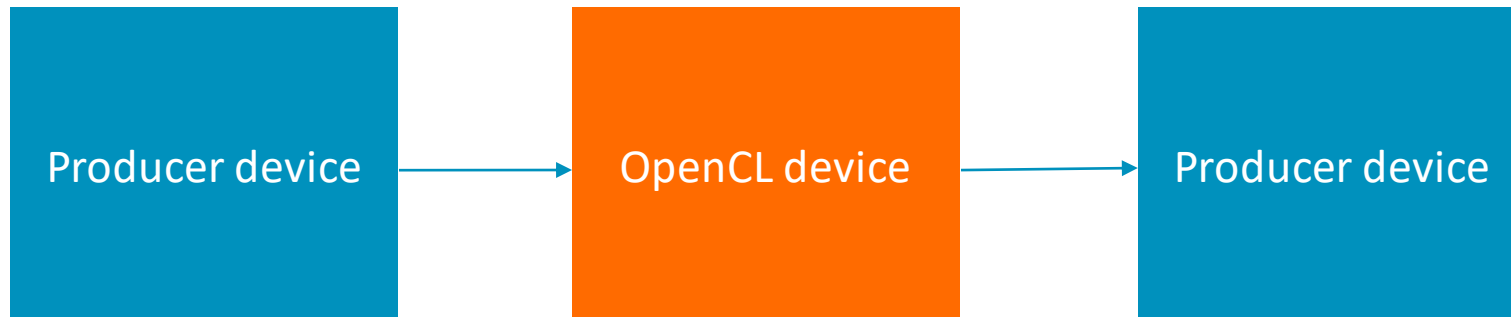


# Some challenges for OpenCL: compression

- Mobile platforms have stringent power constraints (typically 1-3 W)
- Memory bandwidth costs power, say 100mW / GB/s as a rule of thumb
- Compression is important to reducing power
- Cleanly integrating image compression technologies will require overhauling some aspects of image support
  - OpenCL lagging behind in terms of application control
  - See [image tiling control](#) , [DRM format modifier](#) extensions

# Some challenges for OpenCL: latency

- Many use cases are very sensitive to end-to-end latency
  - OpenCL used in a longer processing pipeline
- OpenCL has provided good improvements recently
  - Command buffers
  - External semaphores
- ... but there's more to do.



# Some challenges for OpenCL: Android

- OpenCL is ubiquitous on Android phones
  - Many key product value adds in shipping devices
- ... but not supported officially
- This status-quo is removing opportunities for GPU Compute on mobile devices
- Steer application developers towards Vulkan (officially supported)
  - ... but Vulkan is complex
  - ... and migration is not free
- Layering on top of Vulkan could help
  - Reduce cost for applications and reuse investments in OpenCL

# Any questions?

+ Looking forward to interesting discussions.

+ Join us :)

- <https://careers.arm.com/GPU-at-Arm>
- <https://careers.arm.com/search-jobs/GPU?orgIds=34601&kt=1>

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Thank You

Danke

Gracias

Grazie

谢谢

ありがとう

Asante

Merci

감사합니다

धन्यवाद

Kiitos

شكرًا

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תודה

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