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Toward Performance Portable Programming for Heterogeneous Systems on a Chip: A Case Study with Qualcomm Snapdragon SoC

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U.S. DEPARTMENT OF ENERGY

Heterogeneity in High Performance Computing

Titan (2012)

- CPU
  - AMD Opteron
- Accelerator
  - Nvidia Tesla
- Vendor
  - Cray

Summit (2018)

- CPU
  - IBM Power9
- Accelerator
  - Nvidia Volta
- Vendor
  - IBM

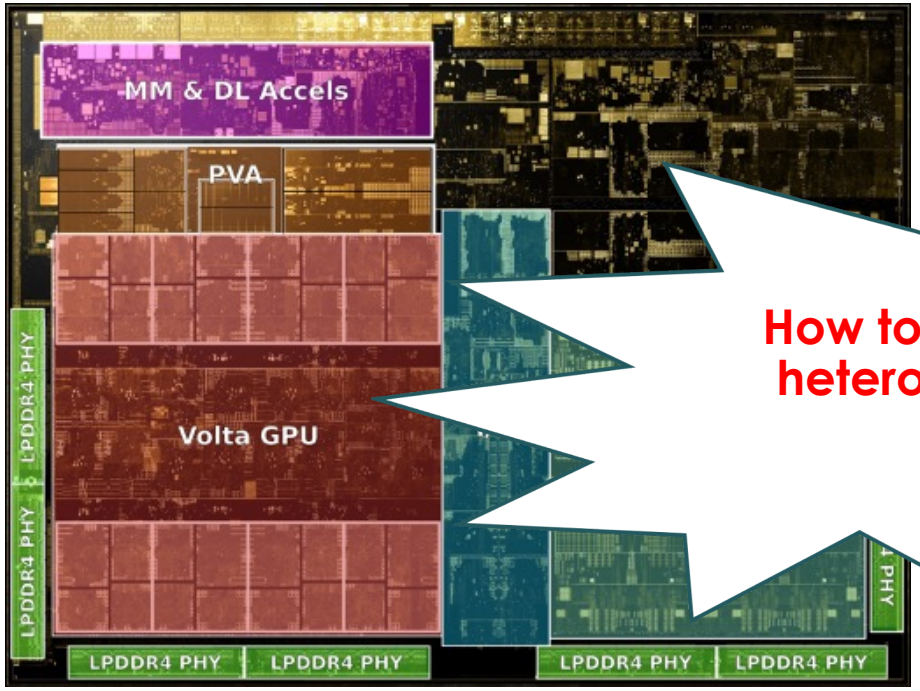
Frontier (2021)

- CPU
  - AMD EPYC
- Accelerator
  - AMD Radeon
- Vendor
  - Cray

Aurora (2022)

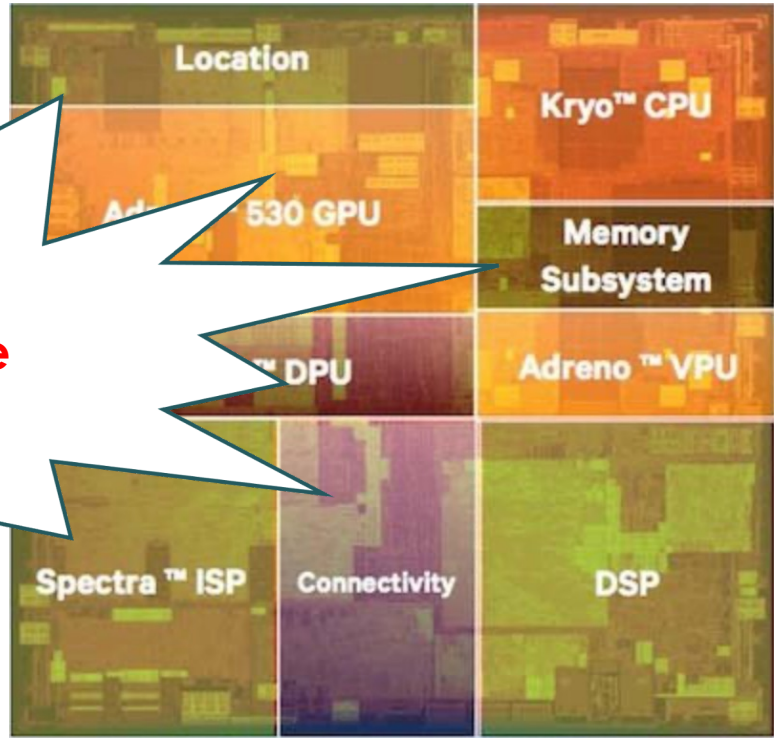
- CPU
  - Intel Xeon
- Accelerator
  - Intel X^e
- Vendor
  - Intel

Programming Heterogeneous Systems is a Bigger Issue in Embedded/Mobile Computing



Xavier SoC from Nvidia

How to program these heterogeneous SoC?



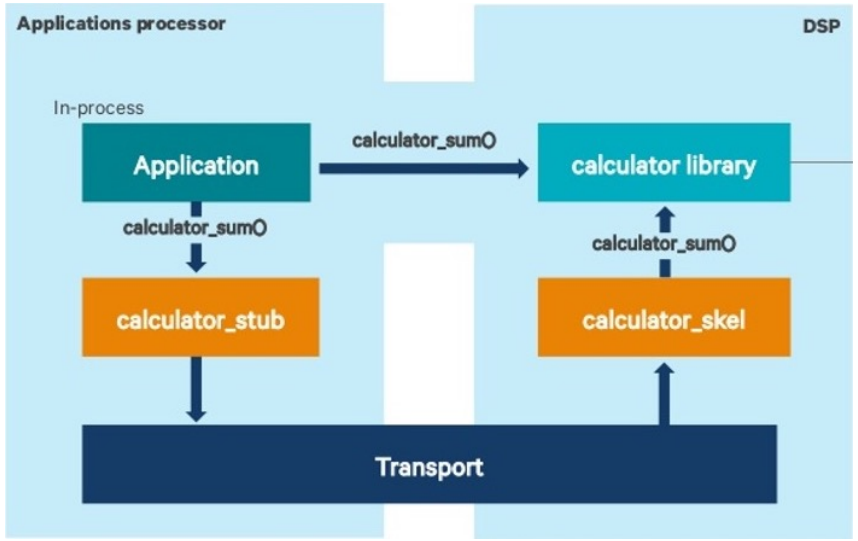
Snapdragon SoC from Qualcomm

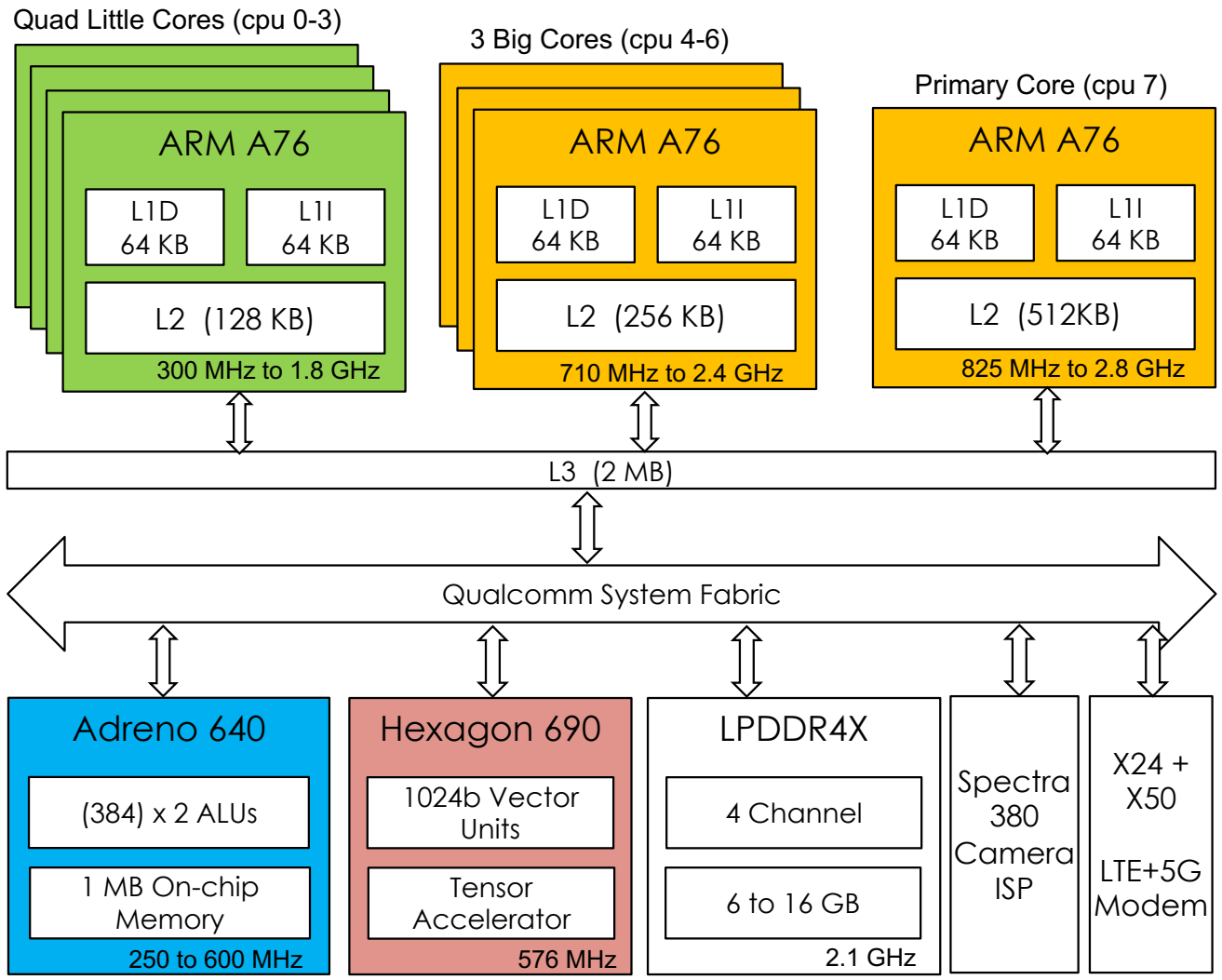
Qualcomm Snapdragon Architecture and Programming

Snapdragon Programming Models

- ARM Kryo CPU: C/C++ with OpenMP
- Adreno GPU: OpenCL, OpenGL, Vulkan, and DirectX
- Hexagon DSP: C/C++ and Assembly language
- Spectra ISP, MDSP, NPU: custom Qualcomm API

Hexagon DSP SDK





Qualcomm Snapdragon Architecture

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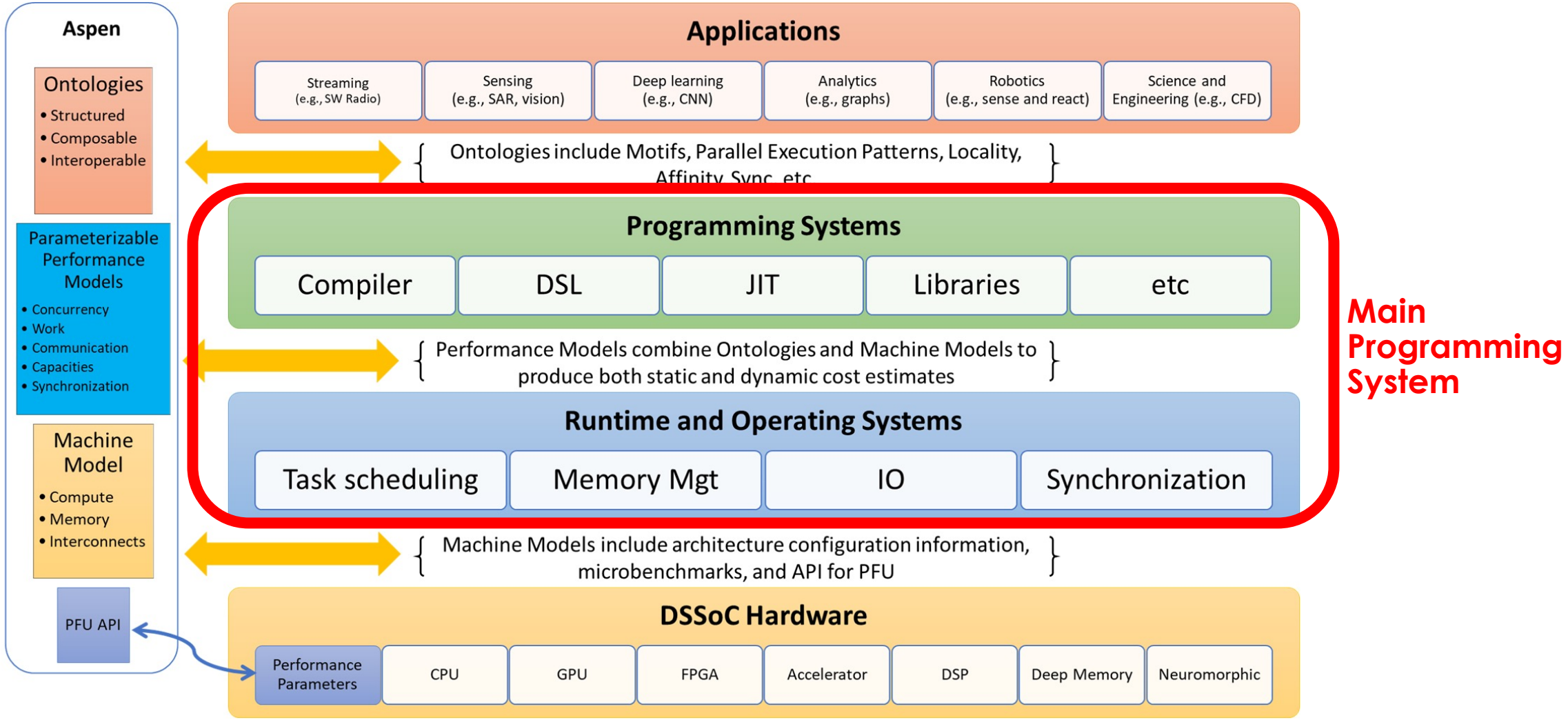
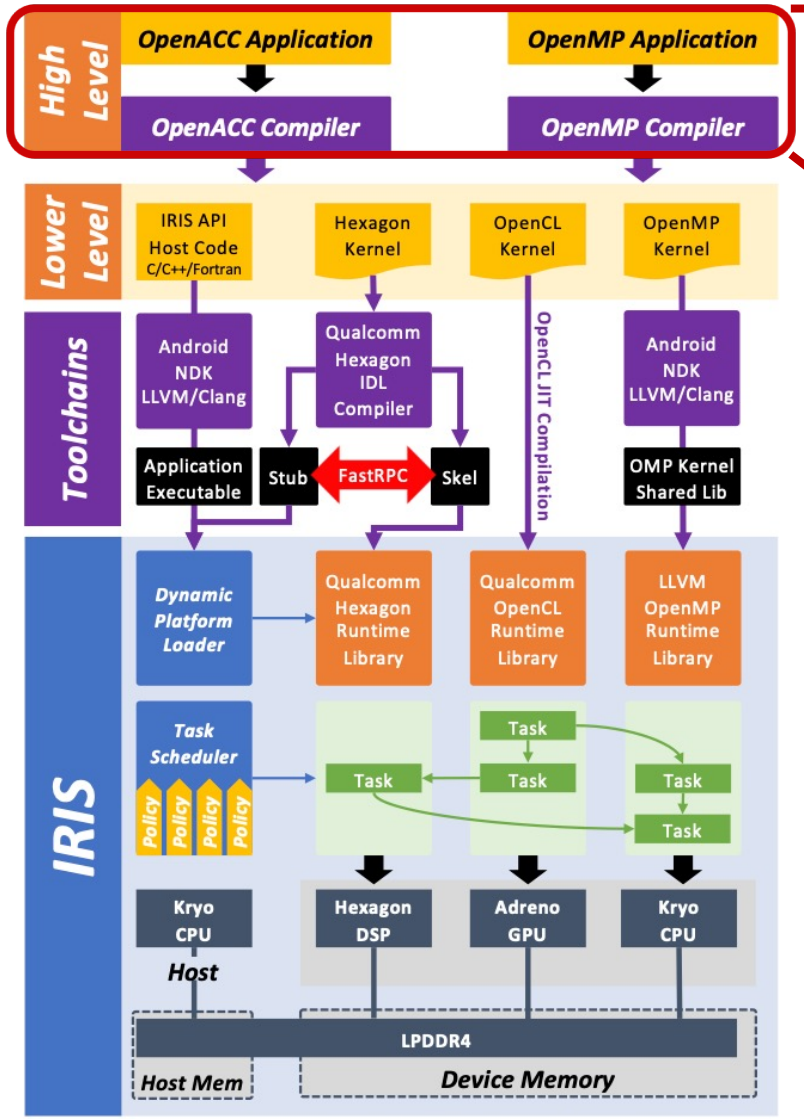
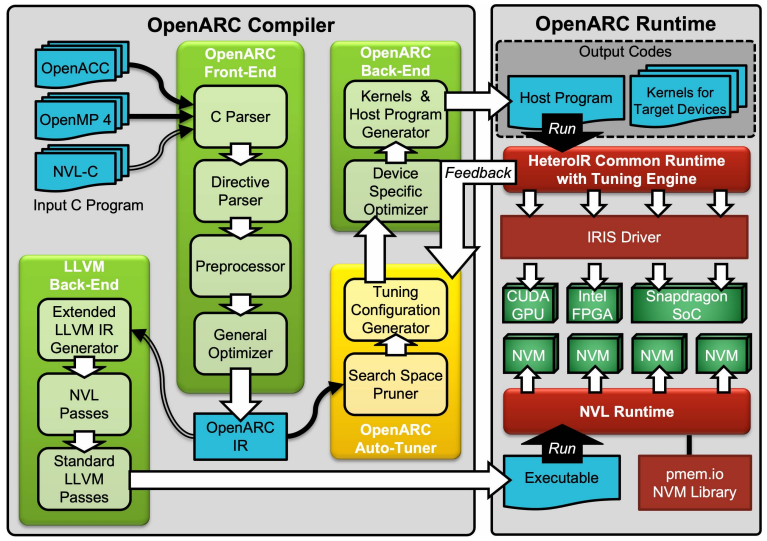
Cosmic Castle for Programming Heterogeneous SoCs



Cosmic Castle Main Programming System



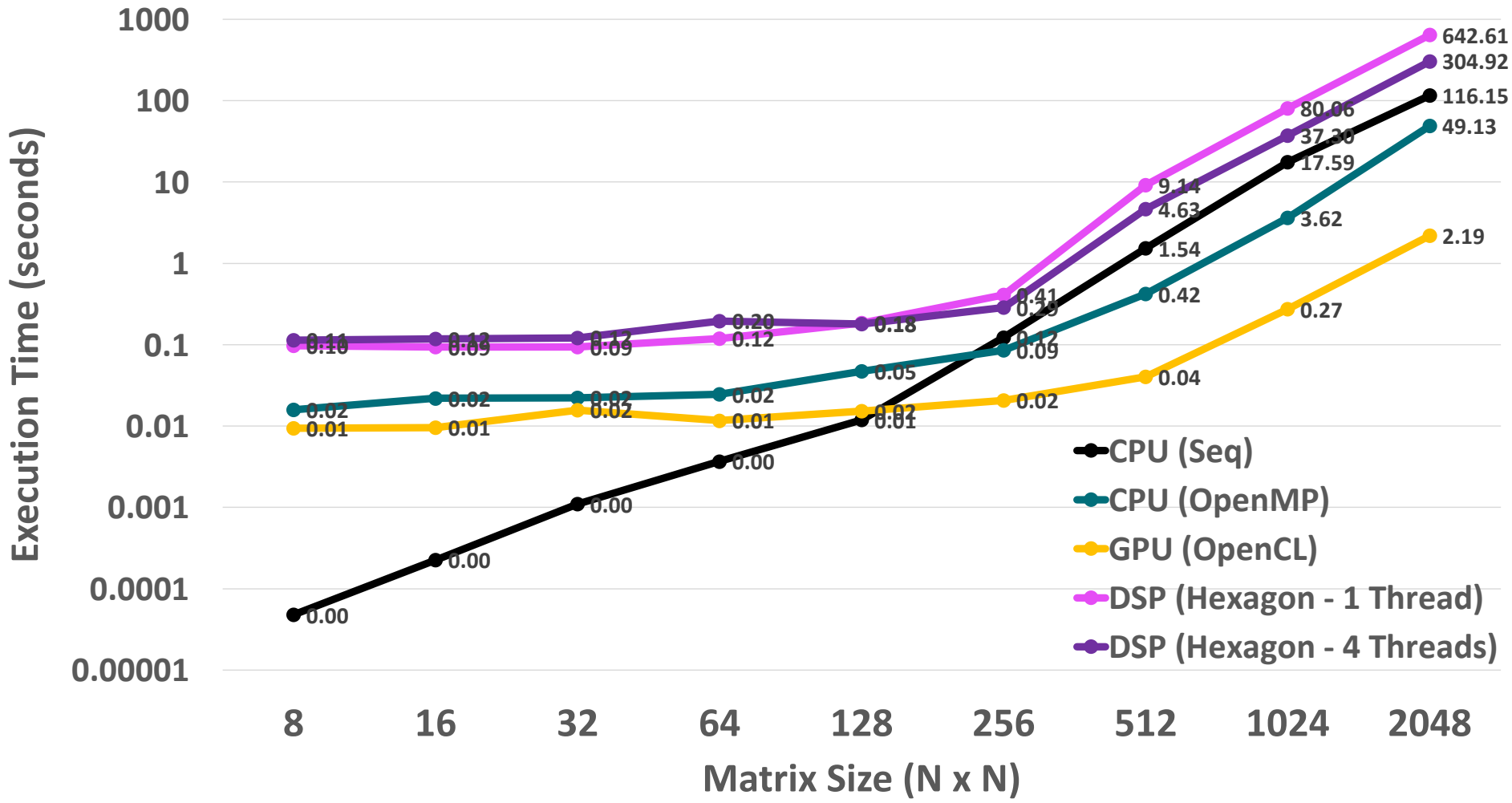
IRIS Runtime for Snapdragon SoC



OpenARC Compiler

- Provide programmers a unified programming environment to write portable code across heterogeneous architectures (and preferred programming systems)
- Orchestrate diverse programming systems (OpenCL, CUDA, HIP, OpenMP, Hexagon) in a single application
- Refer to following papers for more details on IRIS and OpenARC:
  - J. Kim, S. Lee, B. Johnston, and J. S. Vetter, "IRIS: A portable runtime system exploiting multiple heterogeneous programming systems," in IEEE High Performance Extreme Computing (HPEC), 2021.
  - *S. Lee and J. S. Vetter, OpenARC: Extensible OpenACC Compiler Framework for Directive-Based Accelerator Programming Study, Workshop on Accelerator Programming Using Directives (WACCPD) in conjunction with SC14, 2014.*

SGEMM Performance on Snapdragon SoC



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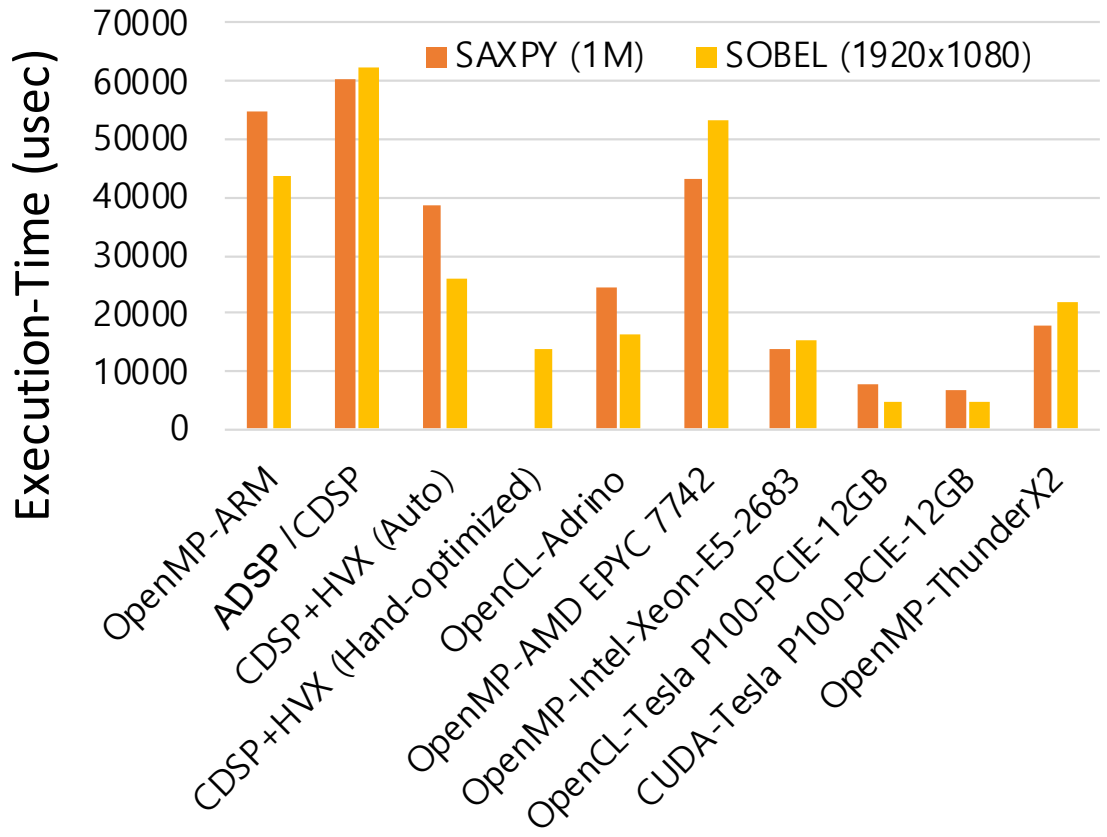
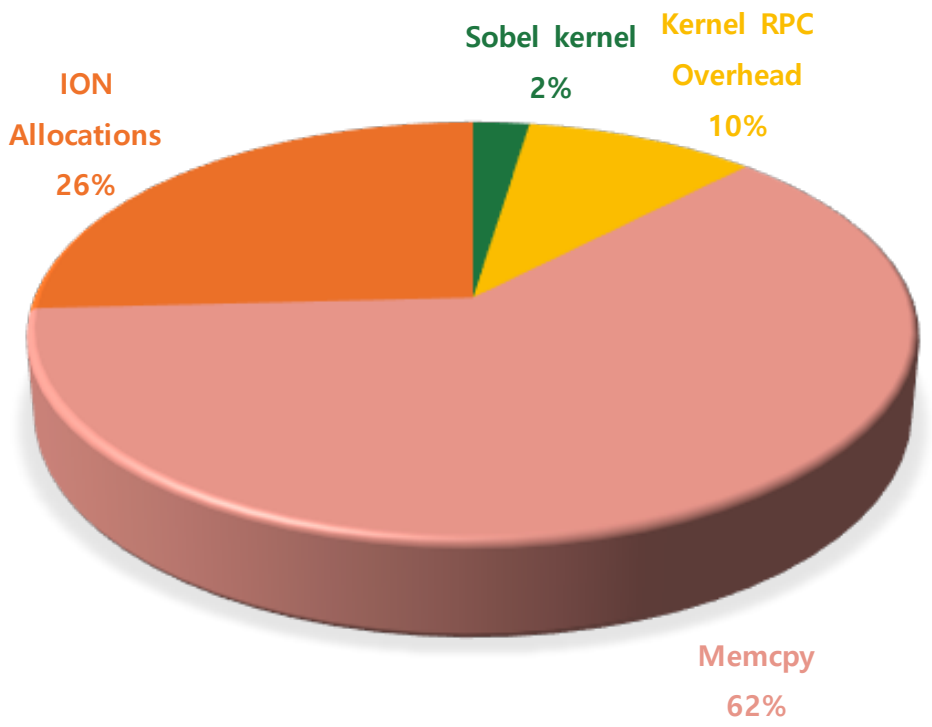
Performance Comparison of Heterogeneous Devices on Snapdragon SoC



SAXPY and Sobel Filter Benchmarking



Runtime-Split of Sobel Filter on Hexagon DSP

Summary

- Cosmic Castle is a software ecosystem for performance portable programming on the heterogeneous SoCs.
- Preliminary evaluation of Cosmic Castle on the Snapdragon SoC shows that Cosmic Castle allows users to program SoCs by using directive-based high-level programming models while exploiting and intermixing different device- specific programming models preferred by each heterogeneous device.
- The initial performance comparison against manual low-level implementations shows the need for exploring further optimization opportunities.

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