MLIR, CIRCT, and AHA

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Overview

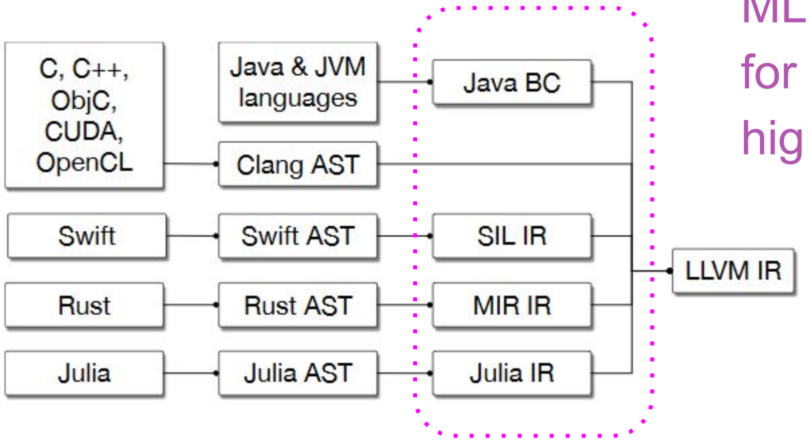
MLIR - Multi-level IR, a toolkit for creating domain-specific IRs (dialects)

CIRCT - Circuit IR Compilers and Tools

How AHA tools might interface with MLIR/CIRCT

MLIR

Motivation: common infrastructure for multi-/mid-level IRs



MLIR is a framework for developing higher-level IRs.

MLIR: A Compiler Infrastructure for the End of Moore's Law
https://arxiv.org/abs/2002.11054v2

MLIR Dialects

A custom IR with its own operations, attributes, and types

Mixable, composable for progressive lowering and expressivity

Dialects declaratively specified using

Operation Definition Specification (ODS)

MLIR Affine dialect operation

```
func @body(index) -> ()

func @simple_loop() {
  affine.for %i = 1 to 42 {
    call @body(%i) : (index) -> ()
  }
  return
}
```

Can mix dialects

```
func @body(index) -> ()

func @simple_loop() {
  affine.for %i = 1 to 42 {
    call @body(%i) : (index) -> ()
  }
  %c1 = constant 1 : index
  %c42 = constant 42 : index
  %c1_0 = constant 1 : index
  scf.for %arg0 = %c1 to %c42 step %c1_0 {
    call @body(%arg0) : (index) -> ()
  }
  return
}
```

Existing Dialects (not exhaustive)

affine - affine operations and analyses / polyhedral stuff

linalg - linear algebra

quant - quantization constraints and transformations

tf - tensorflow

tfl - tensorflow lite

xla - XLA

fir - Fortran

std - standard dialect

scf - structured control flow

pdl - high level abstraction for rewrite patterns

pdl_interp - lower level abstraction for rewrite patterns

llvm - wraps the LLVM IR types and instructions into MLIR

omp - OpenMP

acc - OpenACC

async - modeling asynchronous execution

avx512 - SIMD

vector - abstract SIMD

gpu - middle-level abstractions for launching GPU kernels

nvvm - wraps the NVVM IR (Nvidia)

rocdl - analogous to nvvm dialect but for AMD GPUs

What MLIR provides

Large community of users
Rich ecosystem of dialects
Reduced cost of building a compiler
Target-specific dialect operations
IR specification

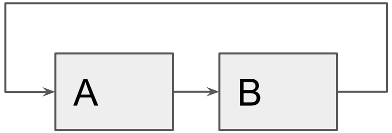
What MLIR won’t provide

Lowering/conversion passes
Type conversion (custom types)
Low level machine code generation
Dialects are not a source language

CIRCT

LLVM incubator project
Goal: MLIR/LLVM development methodology for hardware design tools

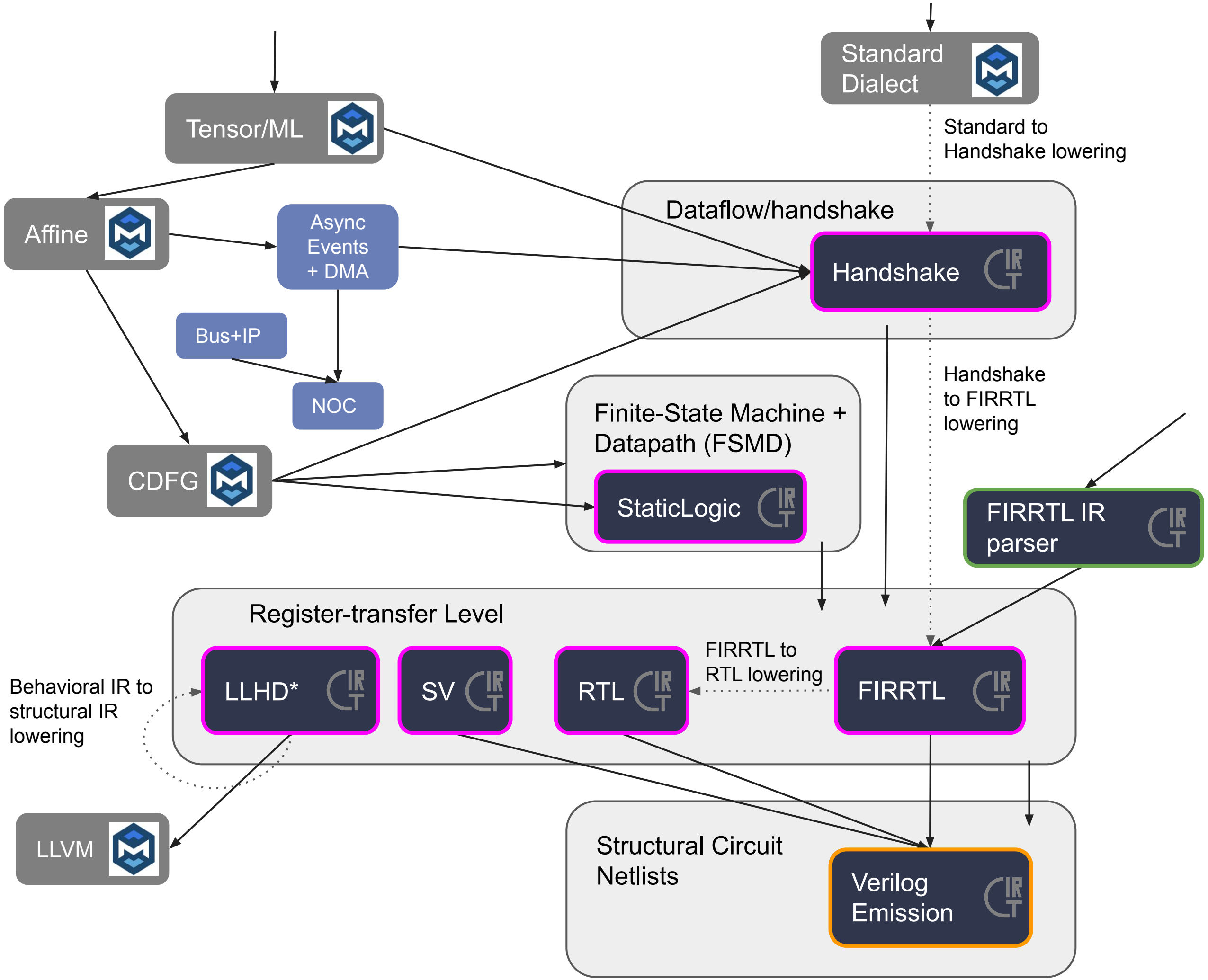
Parallel Compilation => Reduced design time
Multiple Abstractions/Dialect => Improved predictability
Unified Framework => Better integration between high/low level tools
Cyclic SSA graphs (from CIRCT folks) => hardware-oriented semantic models



```
func @arbitrary() {
  %0 = foo.bar(%1)
  %1 = foo.baz(%0)
  return
}
```

Cyclic SSA!

CIRCT


Standard Dialect
Standard to Handshake lowering
Tensor/ML
Affine
Async Events + DMA
Bus+IP
NOC
CDFG
Dataflow/handshake
Handshake
Handshake to FIRRTL lowering
Finite-State Machine + Datapath (FSMD)
StaticLogic
FIRRTL IR parser
Register-transfer Level
LLHD*
SV
RTL
FIRRTL to RTL lowering
FIRRTL
Behavioral IR to structural IR lowering
LLVM
Structural Circuit Netlists
Verilog Emission

Who is involved with CIRCT and MLIR?

MLIR

AMD

arm

cerebras

Google

GRAPHCORE

habana

intel

MEDIATEK

NVIDIA.

Qualcomm

SambaNova SYSTEMS

SAMSUNG

mi

XILINX

CIRT

THE UNIVERSITY OF EDINBURGH

CORNELL UNIVERSITY FOUNDED A.D. 1865

I ILLINOIS

ETH zürich

EPFL

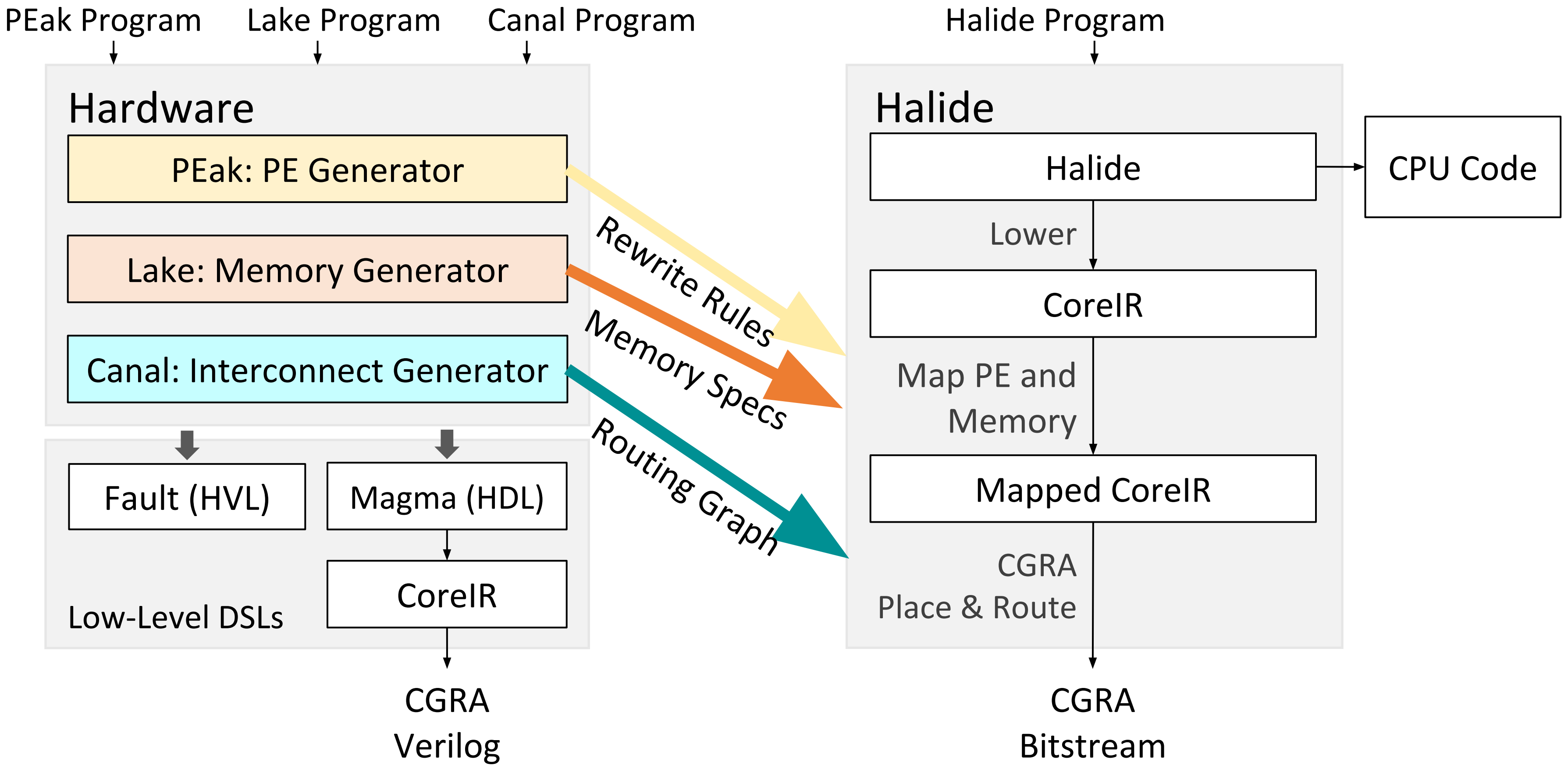
SiFive

XILINX.

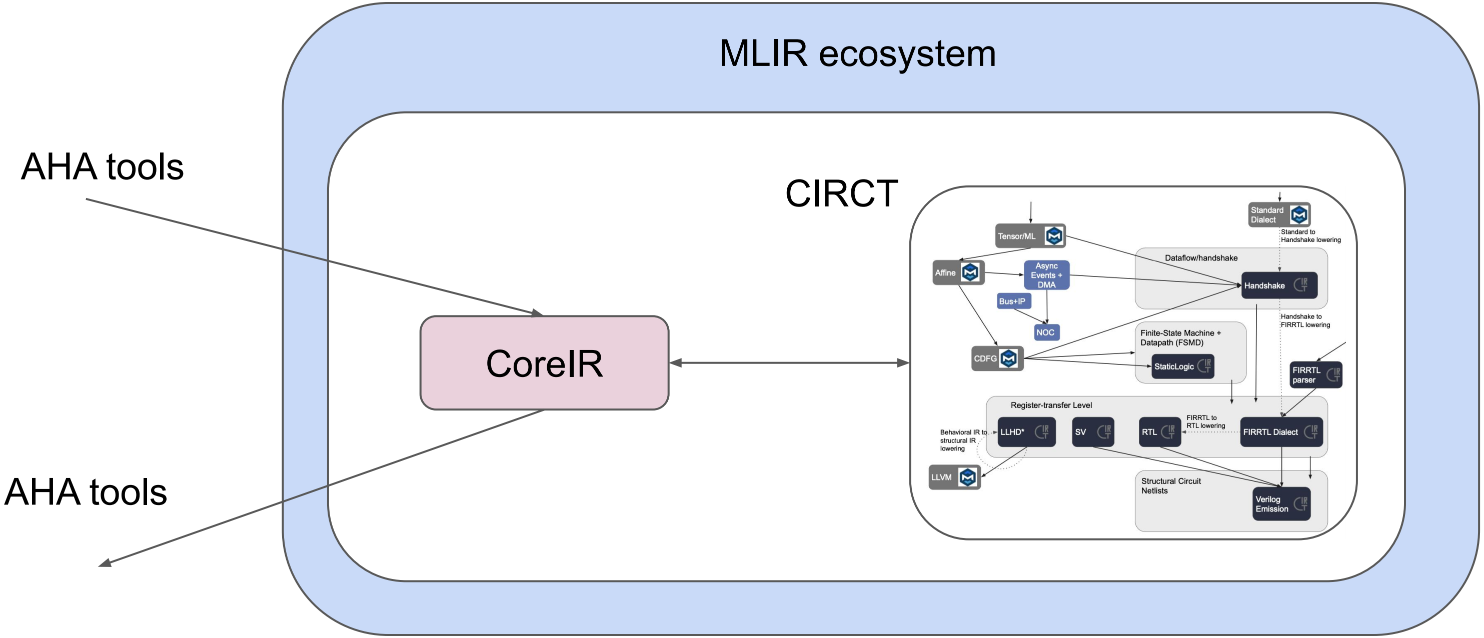
Microsoft

Pacific Northwest NATIONAL LABORATORY

Hardware-Software Compiler Interaction in AHA

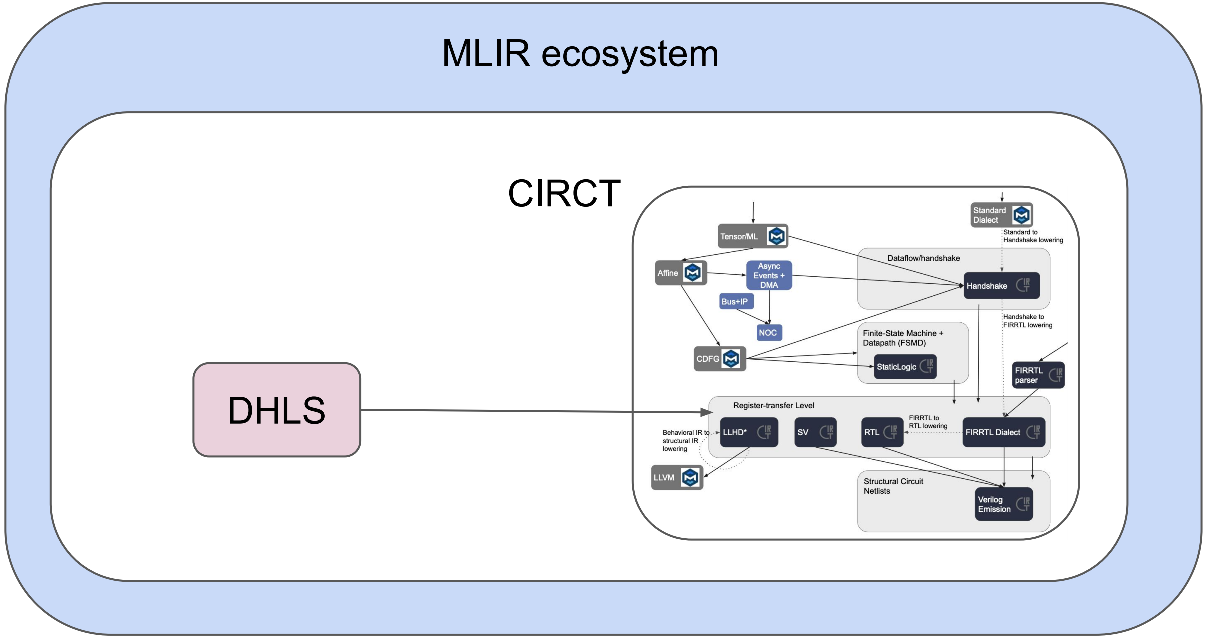


CoreIR and MLIR



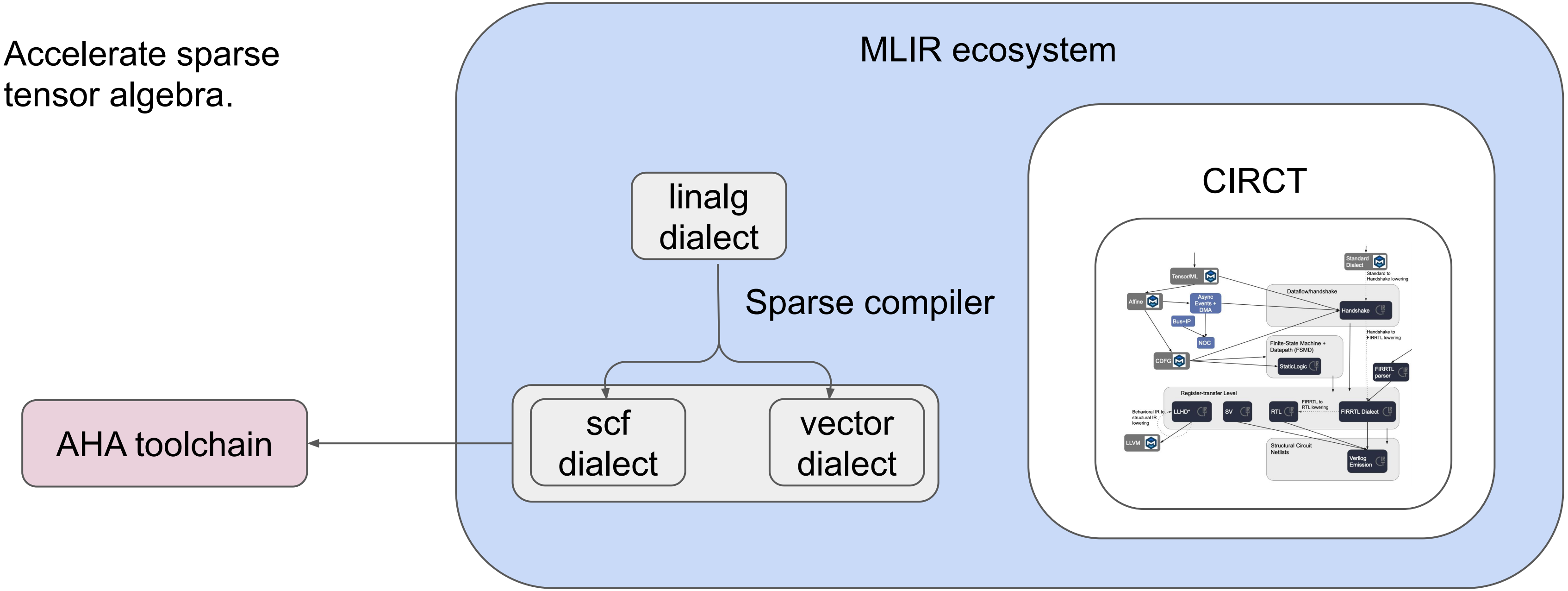
HLS and MLIR

Create an HLS tool designed from the ground up to be used by other compilers as a codegen backend.



Sparsity and MLIR

Accelerate sparse tensor algebra.



MLIR ecosystem

linalg dialect

Sparse compiler

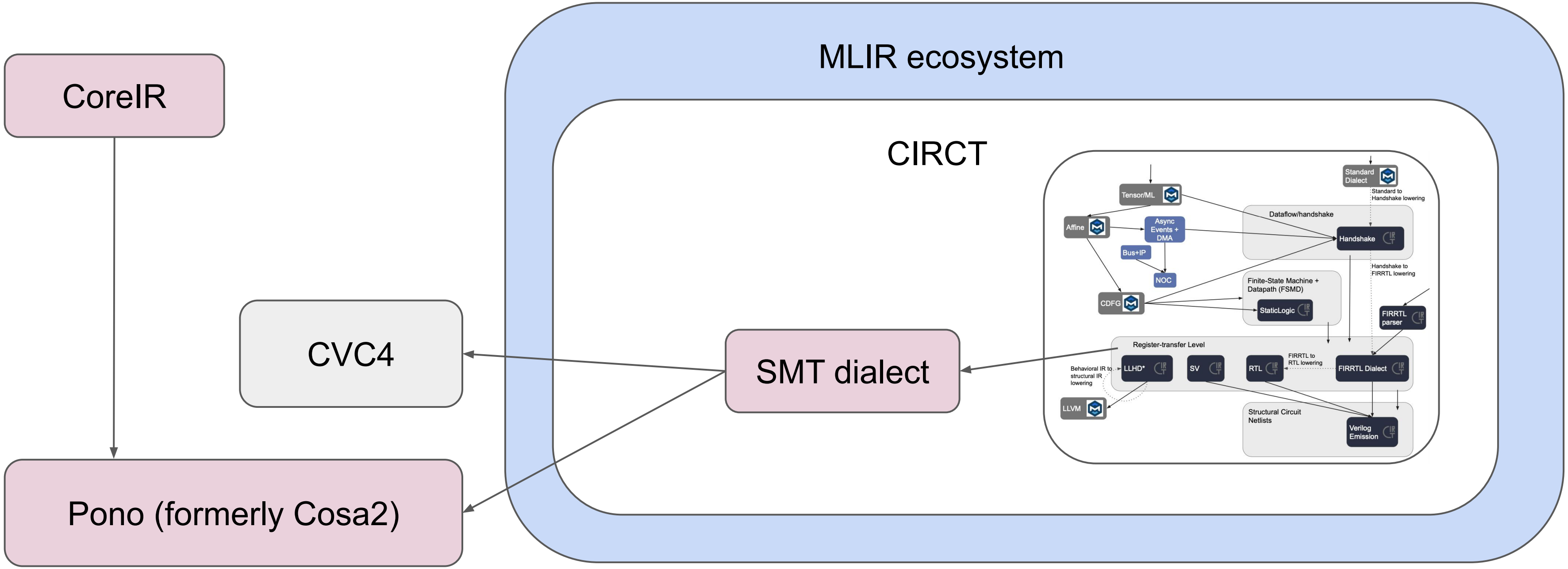
scf dialect

vector dialect

AHA toolchain

CIRCT

SMT and MLIR


MLIR ecosystem
CIRCT
CoreIR
CVC4
SMT dialect
Pono (formerly Cosa2)
Tensor/ML
Standard Dialect
Standard to Handshake lowering
Affine
Async Events + DMA
Bus+IP
NOC
CDFG
Dataflow/handshake
Handshake
Handshake to FIRRTL lowering
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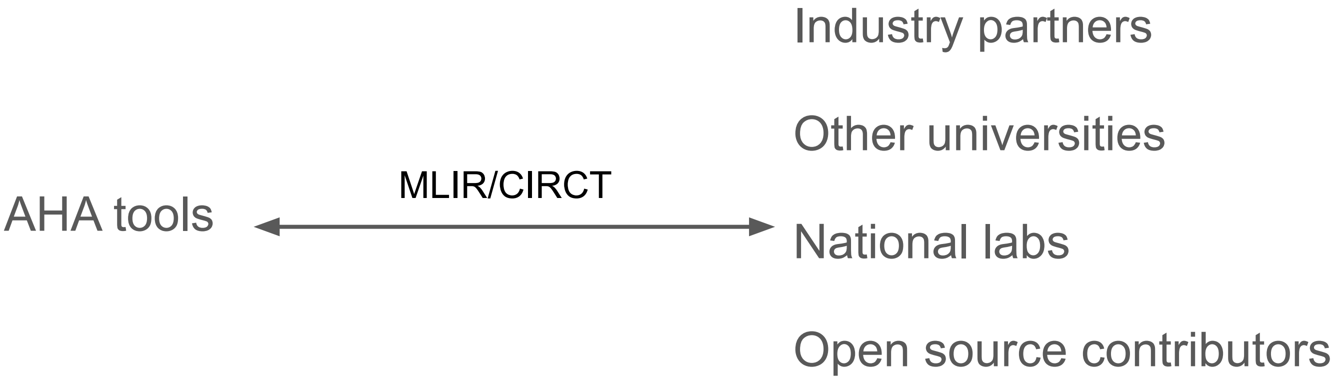
Conclusion



AHA tools

MLIR/CIRCT

Industry partners

Other universities

National labs

Open source contributors