Oak Ridge National Laboratory

JACC
JULIA FOR ACCELERATORS

A Julia Package for HPC Meta-Programming and Performance Portability

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U.S. DEPARTMENT OF ENERGY

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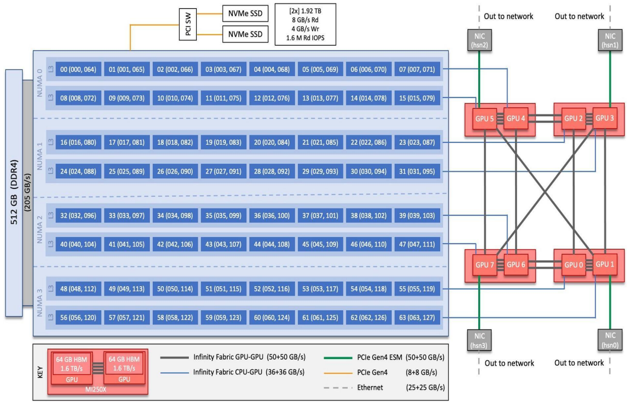
Why Julia?

- Easy to use
- Easy performance
- Easily supported (JIT on top of LLVM)
- Sensible syntax for science
- Easy for HPC packages to provide native syntax (not just wrapping)
- Integrated packaging and testing (reproducibility)
- Easy portability
  (usually just works on a new system…from a developer's standpoint)

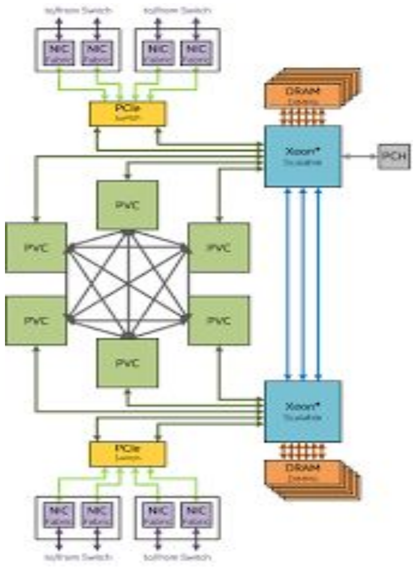
https://julialang.org/

Motivation: Programming Productivity Performance Portability Performance “Practicability”?

- Varied systems
- Varied user expertise

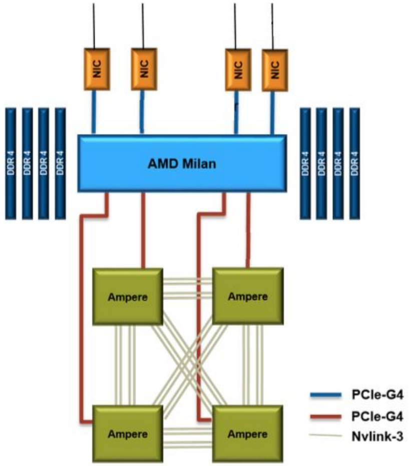


AMD ROCm



oneAPI

SYCL



NVIDIA CUDA

OpenMP

JACC.jl, Julia for ACCelerators

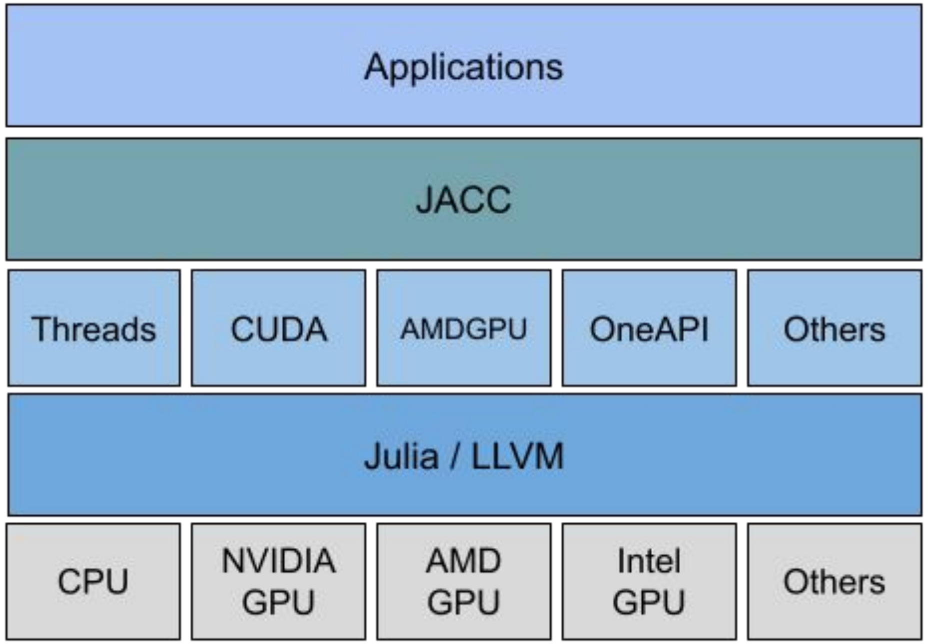
Simple to use performance portable model

- High-level performance portability model (parallel_for & parallel_reduce)
- Unified Julia front-end on top of multiple backends
  - Threads, CUDA, AMDGPU, oneAPI (Metal coming soon)
- Hide low-level, device-specific implementation
  - Memory layout, granularity, etc.
- ***Brings HPC closer to domain scientists***

JACC JULIA FOR ACCELERATORS

https://github.com/JuliaORNL/JACC.jl

https://ieeexplore.ieee.org/document/10820713



Getting started with JACC

1. Add JACC as a dependency

```
julia> Pkg.add("JACC")
```

2. Set backend

```
julia> using JACC
julia> JACC.set_backend("cuda")
```

   - Adds backend package

3. Restart julia

4. Load extension before use

```
julia> using JACC
julia> JACC.@init_backend
```

   - Imports backend package -> activates extension

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JACC paradigm basics - arrays

No JACC-defined array type

```
JACC.array(x::Base.Array)
```

Constructs a backend-specific array (copying to device if necessary)

```
JACC.array_type()
```

Provides type of array that would be returned by JACC.array, e.g., CuArray

```
function foo(x::JACC.array_type(){Float64, 1})
    # ...
end
```

```
JACC.ones, JACC.zeros, JACC.fill
```

JACC paradigm basics - parallel_for

Moving from a serial loop to a JACC.parallel_for

```
for i = 1:N
    @inbounds x[i] += alpha * y[i]
end
```

```
JACC.parallel_for(N, alpha, dx, dy) do i, alpha, x, y
    @inbounds x[i] += alpha * y[i]
end
```

(or, using predefined function)

```
function axpy(i, alpha, x, y)
    @inbounds x[i] += alpha * y[i]
end
JACC.parallel_for(SIZE, axpy, alpha, dx, dy)
```

JACC paradigm basics - parallel_reduce

Examples:

```
elem_sum = JACC.parallel_reduce(a)
elem_min = JACC.parallel_reduce(min, a)

dp = JACC.parallel_reduce(10, a, b) do i, a, b
    @inbounds a[i] * b[i]
end
```

API overview:

```
parallel_reduce(N, f, x...; op, init) -> typeof(init)

parallel_reduce(N, f, x...) = parallel_reduce(N, f, x…; op = +, init = 0.0)

parallel_reduce([op = +,] a::AbstractArray; init = default_init(eltype(a), op)) -> typeof(init)

    # op ∈ {+, *, min, max, custom}
```

Extra Things

LaunchSpec for fine granularity

```
launch_spec(; kw...)

accepts keyword arguments:
     stream
     threads
     blocks
     shmem_size
     sync


spec = JACC.launch_spec(;
          sync = false, threads = 1000)

JACC.parallel_for(spec, N, a_device) do i, a
    @inbounds a[i] += 5.0
end
```

JACC.shared: on-chip shmem

```
function spectral(i, j, image, filter,
num_bands)
    for b in 1:num_bands
        @inbounds image[b, i, j] *= filter[j]
    end
end
```

(just add one line)

```
function spectral(i, j, image, filter,
num_bands)
    filter_sh = JACC.shared(filter)
    for b in 1:num_bands
        @inbounds image[b, i, j] *= filter_sh[j]
    end
end
```

Extra Things (multi-device nodes) (experimental)

JACC.Multi: multi-device “parallelism”

```
alpha = 2.5
dx = JACC.Multi.array(x)
dy = JACC.Multi.array(y)

JACC.Multi.parallel_for(N,a,dx,dy) do i, a, x, y
    @inbounds x[i] += alpha * y[i]
end
```

With extra methods for handling ghost elements

JACC.Async: multi-device “concurrency”

```
JACC.Async.parallel_for(1, ...)
JACC.Async.parallel_for(2, ...)
JACC.Async.synchronize()

# parallel_reduce return value is on device
res_d = JACC.Async.parallel_reduce(1, ...)
res = JACC.to_host(res_d)[]
```

Applications & Future Work

- Ongoing Efforts
  - Performance benchmarking (closing gaps)
  - More intuitive kernel launch
  - JACC.Auto : Autotuning
  - Have ideas? Send us a message!
- Examples and applications using JACC
  - Look at the tests
  - Tatiana's 7-point stencil
  - https://github.com/JuliaORNL/MiniVATES.jl
  - https://github.com/JuliaORNL/JACC-applications
  - https://github.com/JuliaORNL/GrayScott.jl
- Other HPC Julia tutorial resources
  - SC24 tutorial

Project:

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- Narasinga Rao Miniskar (ORNL)
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- Karl Pierce (Flatiron Institute)
- Kelly Tang
- Tatiana Melnichenko

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Questions?