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Parallel Runtime Interface for Fortran

A compiler and implementation independent interface for supporting the parallel features of the Fortran language

https://go.lbl.gov/prif

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Outline

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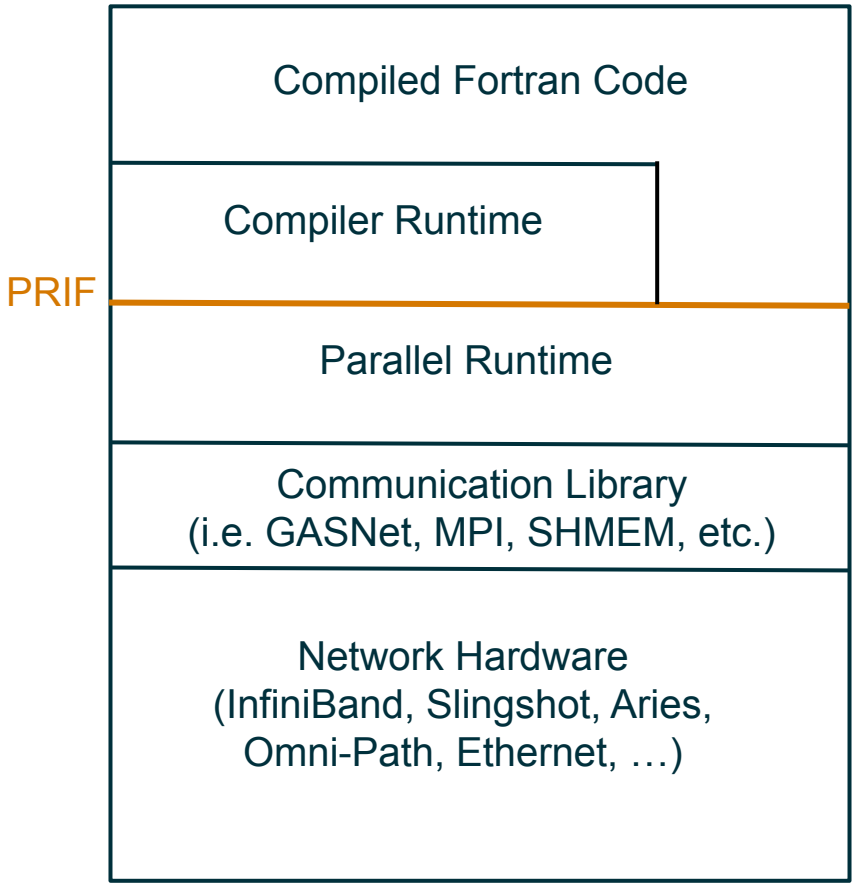
Motivation

What's this for?

- Enable a compiler to target multiple implementations of PRIF
  - I.e. enable a vendor to supply their own parallel runtime
- Enable a PRIF implementation to be used by multiple compilers
- Isolate a compiler's support of the parallel features of the language from any particular details of the communication infrastructure
- Our group's experience with UPC and OpenCoarrays has shown this to be valuable



Parallel Features

- Statements
  - Synchronization
    - Explicit: `sync all`, `sync images`, `sync memory`, `sync team`
    - Implicit: `allocate`, `deallocate`, `stop`, `end`, `move_alloc`
  - Events: `event post`, `event wait`
  - Notify: `notify wait`
  - Error termination: `error stop`
  - Locks: `lock`, `unlock`
  - Failed images: `fail image`
  - Teams: `form team`, `change team`
  - Critical sections: `critical`, `end critical`
- Coarray Accesses (`[...]`)
- Intrinsic functions: `num_images`, `this_image`, `lcobound`, `ucobound`, `team_number`, `get_team`, `failed_images`, `stopped_images`, `image_status`, `coshape`, `image_index`
- Intrinsic subroutines
  - Collective subroutines: `co_sum`, `co_max`, `co_min`, `co_reduce`, `co_broadcast`
  - Atomic subroutines: `atomic_add`, `atomic_and`, `atomic_cas`, `atomic_define`, `atomic_fetch_add`, `atomic_fetch_and`, `atomic_fetch_or`, `atomic_fetch_xor`, `atomic_or`, `atomic_ref`, `atomic_xor`
  - Other subroutines: `event_query`
- Types, kind type parameters, and values
  - Intrinsic derived types: `event_type`, `team_type`, `lock_type`, `notify_type`
  - Atomic kind type parameters: `atomic_int_kind` and `atomic_logical_kind`
  - Values: `stat_failed_image`, `stat_locked`, `stat_locked_other_image`, `stat_stopped_image`, `stat_unlocked`, `stat_unlocked_failed_image`

PRIF Design Overview

Parallel Features Directly Translatable to Use of Fortran Library

```
me = this_image()

call co_sum(a, result_image=1)


arr[1] = some_calc()
```

```
call prif_this_image(image_index=me)

call prif_co_sum( &
    a, result_image=1_c_int)


call prif_put( &
    arr_coarray_handle, &
    int([1], c_intmax_t), &
    some_calc(), &
    int(storage_size(arr)/8, c_size_t), &
    c_loc(arr))
```

PRIF Design Overview: Responsibilities

Compiler

- Establish and initialize static coarrays prior to main
- Track corank of coarrays
- Track local coarrays for implicit deallocation when exiting a scope
- Initialize a coarray with SOURCE= as part of allocate-stmt
- Provide prif_critical_type coarrays for critical-constructs
- Provide final subroutine for all derived types that are finalizable or that have allocatable components that appear in a coarray
- Variable allocation status tracking, including use of MOVE_ALLOC

PRIF Implementation

- Track coarrays for implicit deallocation at end-team-stmt
- Allocate and deallocate a coarray
- Reference a coindexed-object
- Team stack abstraction
- form-team-stmt, change-team-stmt, end-team-stmt
- Intrinsic functions related to parallel Fortran, like num_images, etc
- Atomic subroutines
- Collective subroutines
- Synchronization statements
- Events, notify
- Locks
- critical-construct

Next Steps

- Submit PRIF Design Doc to LLVM-Project Repository
- Finish tests for proper behaviour of parallel features
- Finish implementation in Caffeine
- (Find help with) Integration into flang
- Track progress: https://github.com/BerkeleyLab/flang-testing-project/projects/7
- Solicit Feedback:
  - Discourse Post
  - Email: lbl-flang@lbl.gov
  - Specification Working Draft: https://go.lbl.gov/prif
  - We welcome issues and PRs at the above GitHub Repository

Questions?

- Email: lbl-flang@lbl.gov
- Specification Working Draft: https://go.lbl.gov/prif

Acknowledgements

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Who We are

We have experience developing parallel runtimes, parallel applications, Flang frontend parallel features, and parallel unit tests:

- **OpenCoarrays:** Fanfarillo, A., Burnus, T., Cardellini, V., Filippone, S., Nagle, D., & Rouson, D. (2014). "OpenCoarrays: open-source transport layers supporting coarray Fortran compilers." In *Proceedings of the 8th International Conference on Partitioned Global Address Space Programming Models* (pp. 1-11). doi: 10.1145/2676870.2676876
- **Caffeine:** Rouson, D., & Bonachea, D. (2022). "Caffeine: CoArray Fortran Framework of Efficient Interfaces to Network Environments." In *2022 IEEE/ACM Eighth Workshop on the LLVM Compiler Infrastructure in HPC (LLVM-HPC)* (pp. 34-42). IEEE. doi: 10.25344/S4459B
- **Flang:** Rasmussen, K., Rouson, D., George, N., Bonachea, D., Kadhem, H., & Friesen, B. (2022) "Agile Acceleration of LLVM Flang Support for Fortran 2018 Parallel Programming", Research Poster at the International Conference for High Performance Computing, Networking, Storage, and Analysis (SC22). doi: 10.25344/S4CP4S
- **Berkeley UPC**: Chen, Bonachea, Duell, Husbands, Iancu, Yelick,, "A Performance Analysis of the Berkeley UPC Compiler", Proceedings of the International Conference on Supercomputing (ICS), ACM, June 23, 2003, 63--73, doi: 10.1145/782814.782825
- **UPC++:** Bachan, Baden, Hofmeyr, Jacquelin, Kamil, Bonachea, Hargrove, Ahmed, "UPC++: A High-Performance Communication Framework for Asynchronous Computation", 33rd IEEE International Parallel & Distributed Processing Symposium (IPDPS'19), May 2019, doi: 10.25344/S4V88H

Why not OpenCoarrays?

- Is hardwired to gfortran, e.g., many procedures manipulate gfortran-specific descriptors
- The interface implicitly assumes a MPI backend
- Only the MPI layer is maintained (GASNet & OpenSHMEM layers are legacy codes)
- Lacks full support for some parallel features (e.g., teams).
- Has a bus factor of ~1.

What is GASNet?