LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

The DASH Coarray Abstraction

www.dash-project.org

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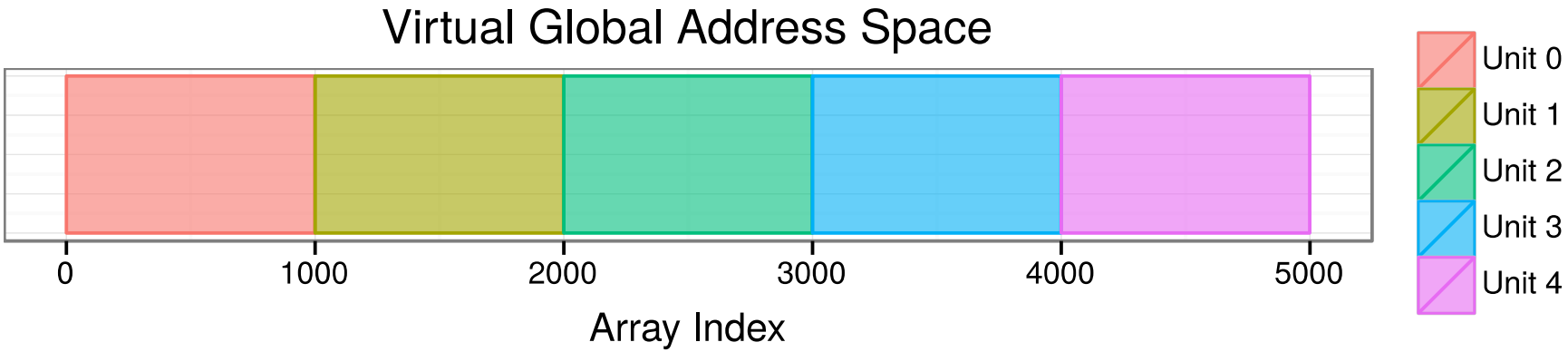
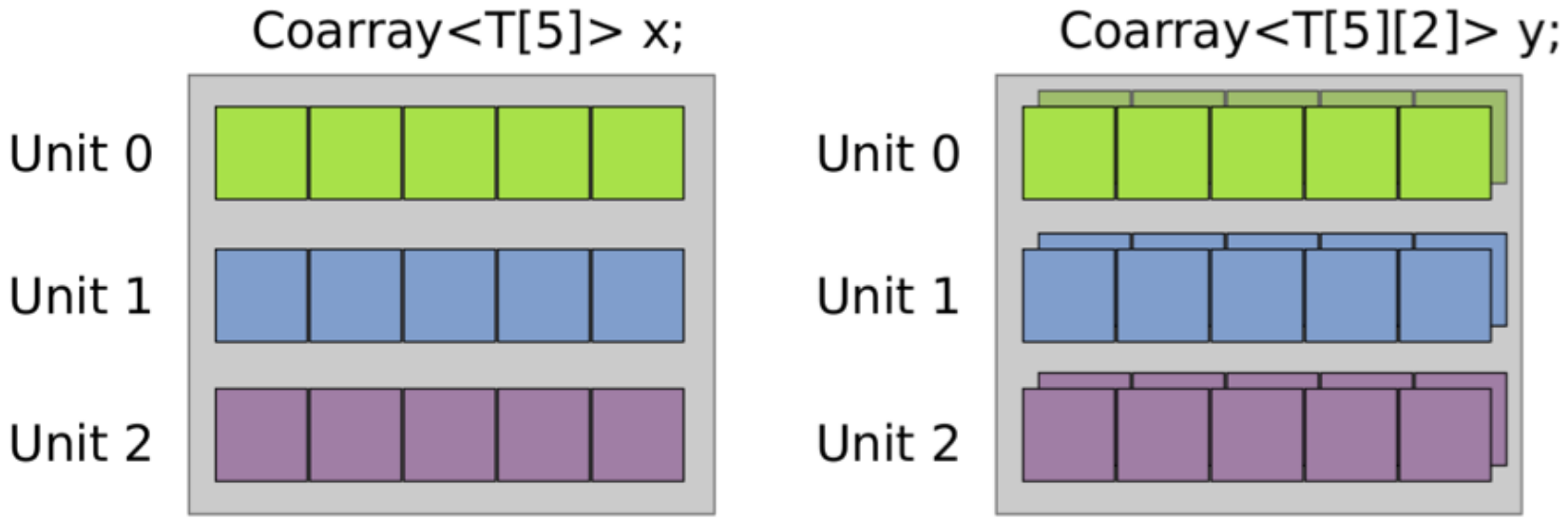
DASH - Overview

- PGAS
  - Data is distributed over units
  - Global data structures know its layout
- DASH
  - C++ library similar to UPC++
  - Implements PGAS approach
  - Provides distributed data structures and algorithms



Coarray - Overview

- Implements PGAS programming model
  - Part of Coarray Fortran (CAF 2008)
- CAF program executed as loosely coupled set of processes, following SPMD
- Extends array syntax with a remote dimension



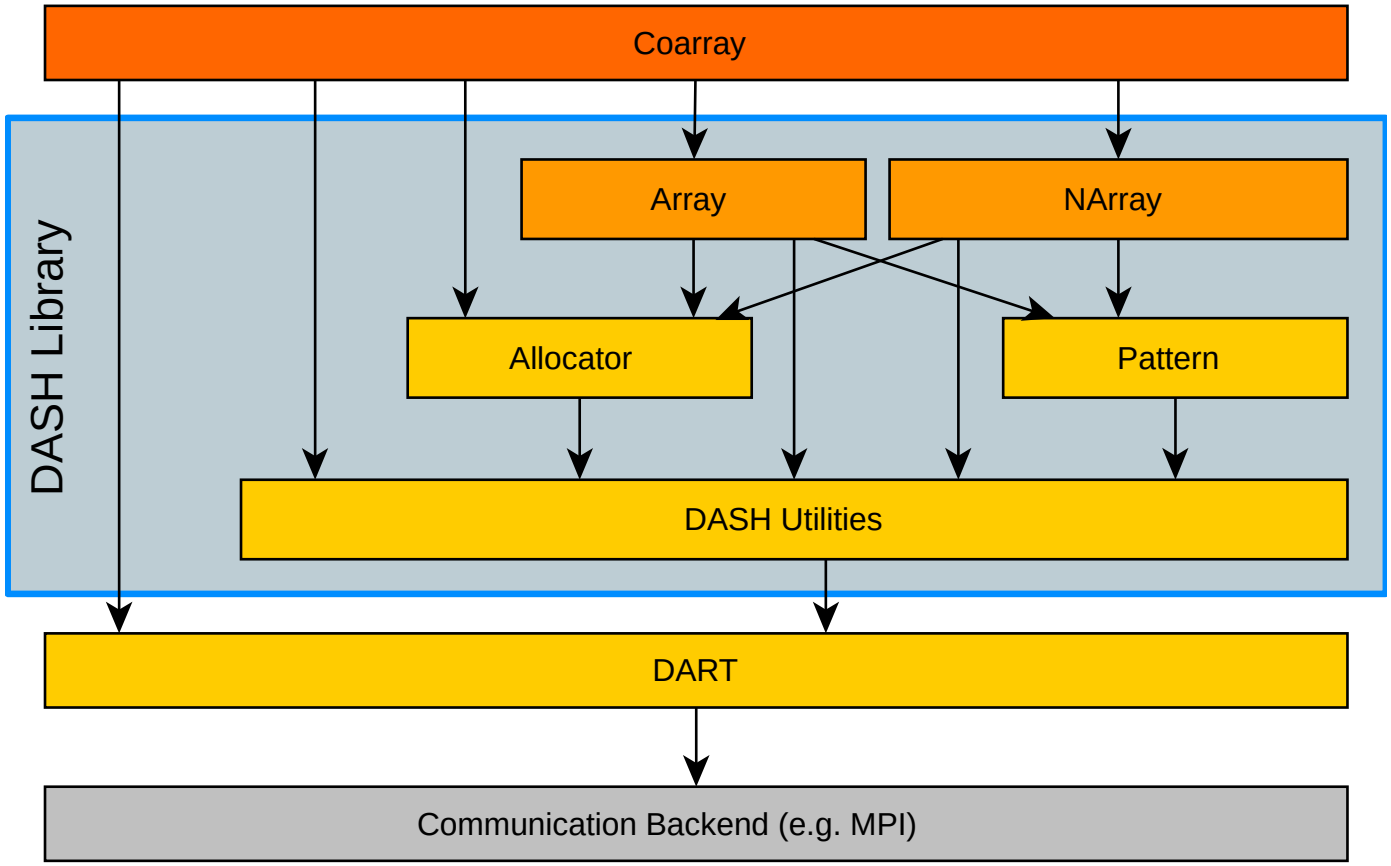
Coarray – Design Goals

- Interface similar to CAF
- Good integration with DASH + STL concepts
- Easy to use
- Reasonable performance

Is it useful?

- Yes, use rich C++ features
- Yes, easy integration

Coarray System Diagram



Arithmetic Operations on scalar Coarray

- Idea: Use scalar Coarray as number
  - Requires blocking gets
  - Globally overloading all arith. operators
- Scenarios
  - T + Coarray<T>
  - Coarray<T> + T
  - Coarray<T> + Coarray<T>
- Non-blocking put for performance

```
Coarray<int> x;
x += 1;
x = x(1) + 1;
x = 1 + x(1);
```

DASH Coarray Interface

- Implements container concept
- Provides linear access
  - To local and global elements
  - By using iterators

```
dash::CoArray<int[10][20]> x;

// global iterators to full range
GlobIter<int> gbegin = x.begin();
GlobIter<int> gend   = x.end();
// global iterator to range on single unit (might not be local)
GlobIter<int> gbegin = x(0).begin();
GlobIter<int> gbegin = x(0).end();
// local iterator to local range. Can be implemented using pointers
local_iterator<int> lbegin = x.lbegin();
local_iterator<int> lend   = x.lend();
```

Additional Structures

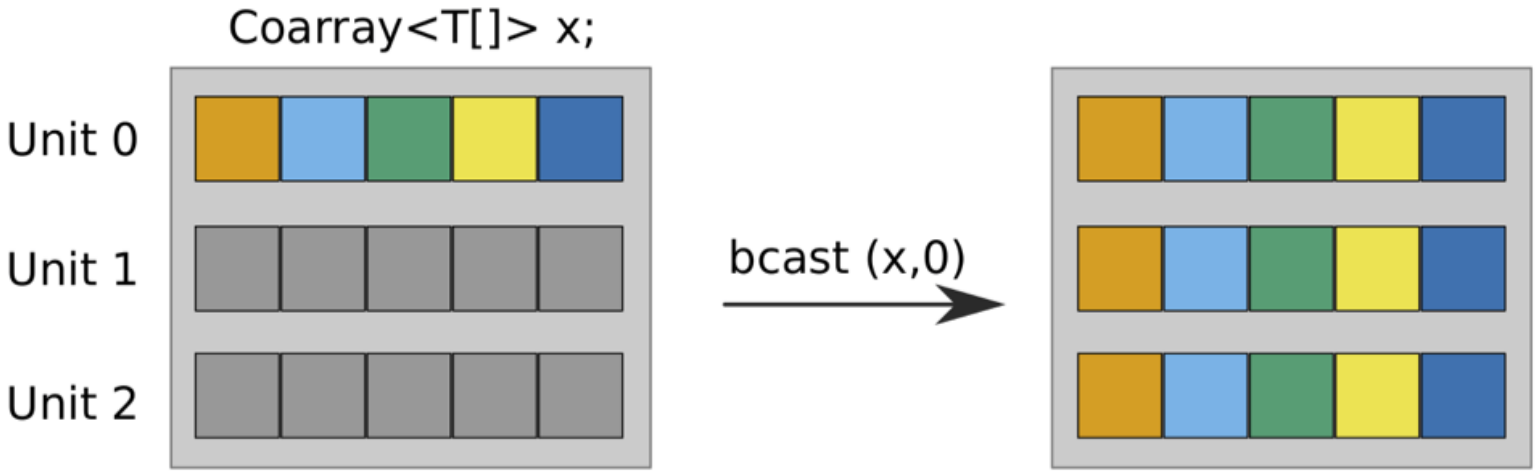
- Copointers => Implemented as GlobPtr
  - GlobPtr can be placed in Coarray
  - Point to arbitrary location in GAS
- Synchronization mechanisms
  - sync_all()
  - sync_images(list_of_images)
- Atomics
- Collective operations
- Comutex, Coevent
- Helpers for compound types

Atomic Operations

- Coarray<Atomic<int>[10]>
- Provides atomic access on elements, e.g
  - load, store
  - add, fetch_and_op
  - compare_exchange
- Implemented by specializing GlobRef<atomic<T>>
- Important: No local access using pointers

Collective Operations – Coarray Interface

- Broadcast (local element(s) to all units)
- Reduce (broadside reduction of local parts)



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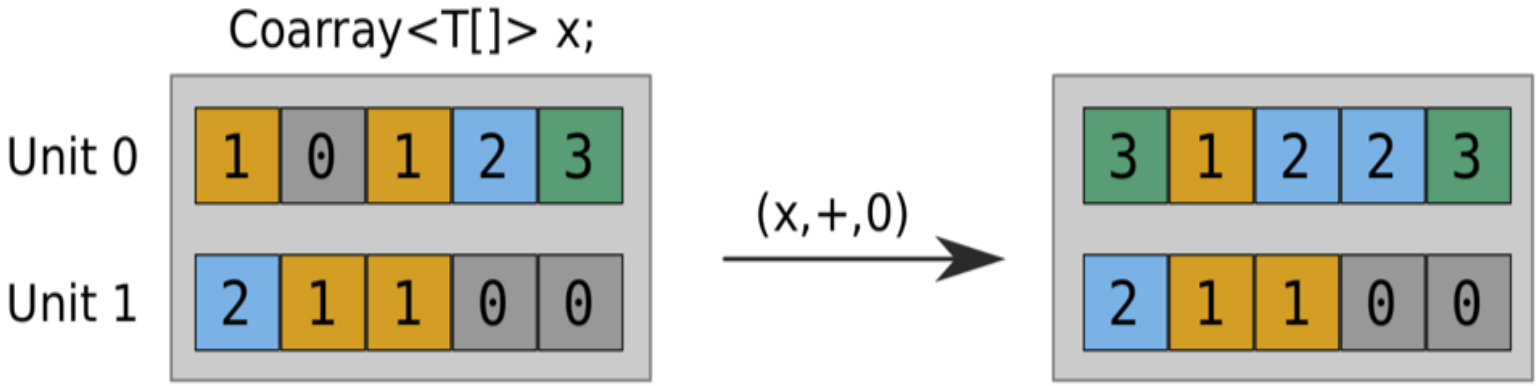


Collective Operations – Container Interface

- Supports all DASH + STL algorithms
  - copy, foreach, min, max, …
- Supports arbitrary ranges by using iterators
- No “range-references”

```
dash::Coarray<int[10][20]> x;
dash::fill(x.begin(), x.end(), 2);
dash::for_each(x(1).begin(), x(3).end(),...);
std::fill(x.lbegin(), x.lend(), 2);
```

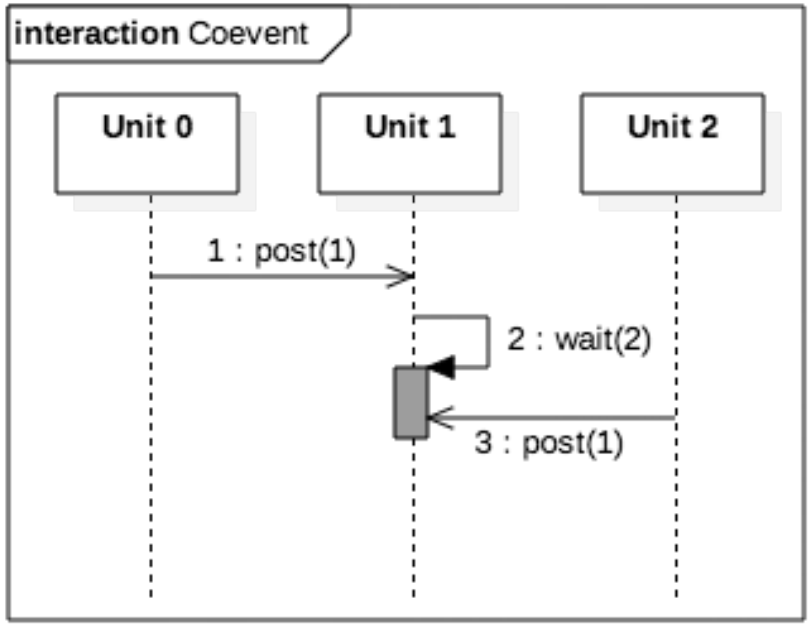
Comutex

- Mutual exclusion on per unit basis
- Compatible with std::lock_guard
- Internally uses dash::Mutex

```
Comutex comx;
{
    int unit = 1; // in [0,num_images()-1]
    std::lock_guard<dash::Mutex> lg(comx(unit));
    // do something critical
}
```

Coevent - Interface

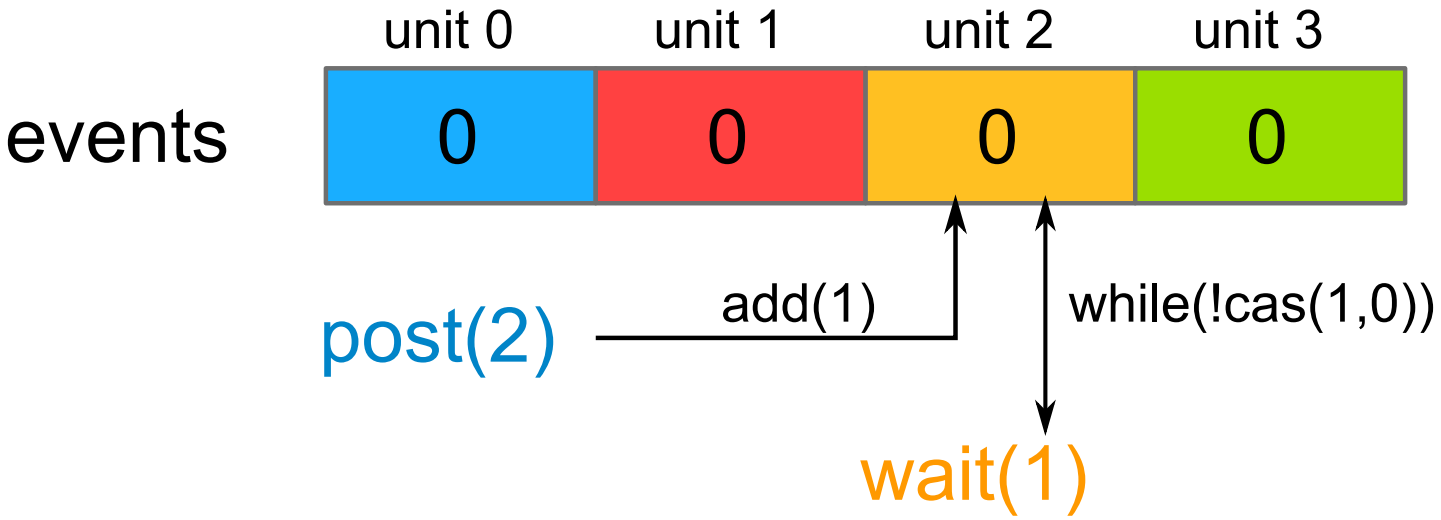
- Similar to proposed CAF Events
- Simplistic P2P synchronization
- Post(target) Wait(num)



Highly Scalable Ref. Implementation

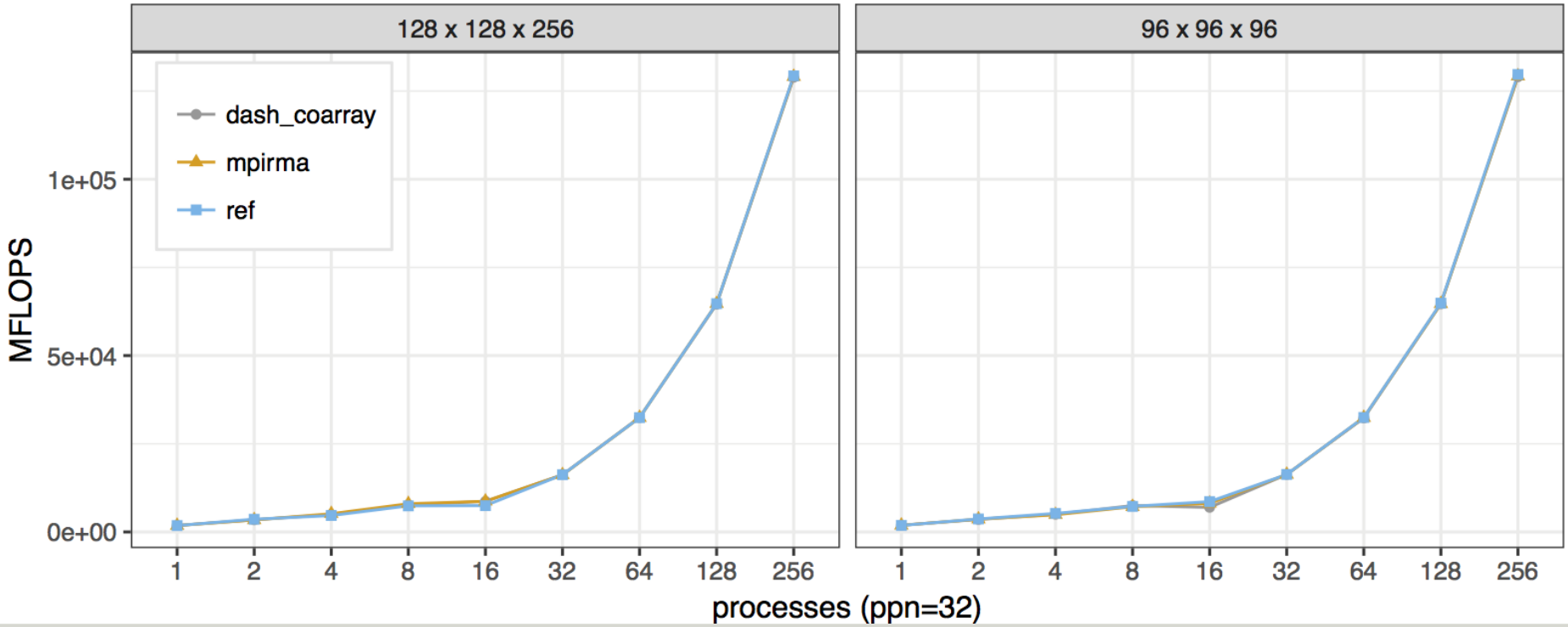
CoEvent - Implementation

- Pure one-sided communication
- Waiting by spinning on atomics



Evaluation

- HPCCG Benchmark (Cori - HW)
  - CG solver on 3D chimney domain
  - No communication / computation overlap
  - Coevent for signalling completion of data transfer
  - Blockwise data transfer



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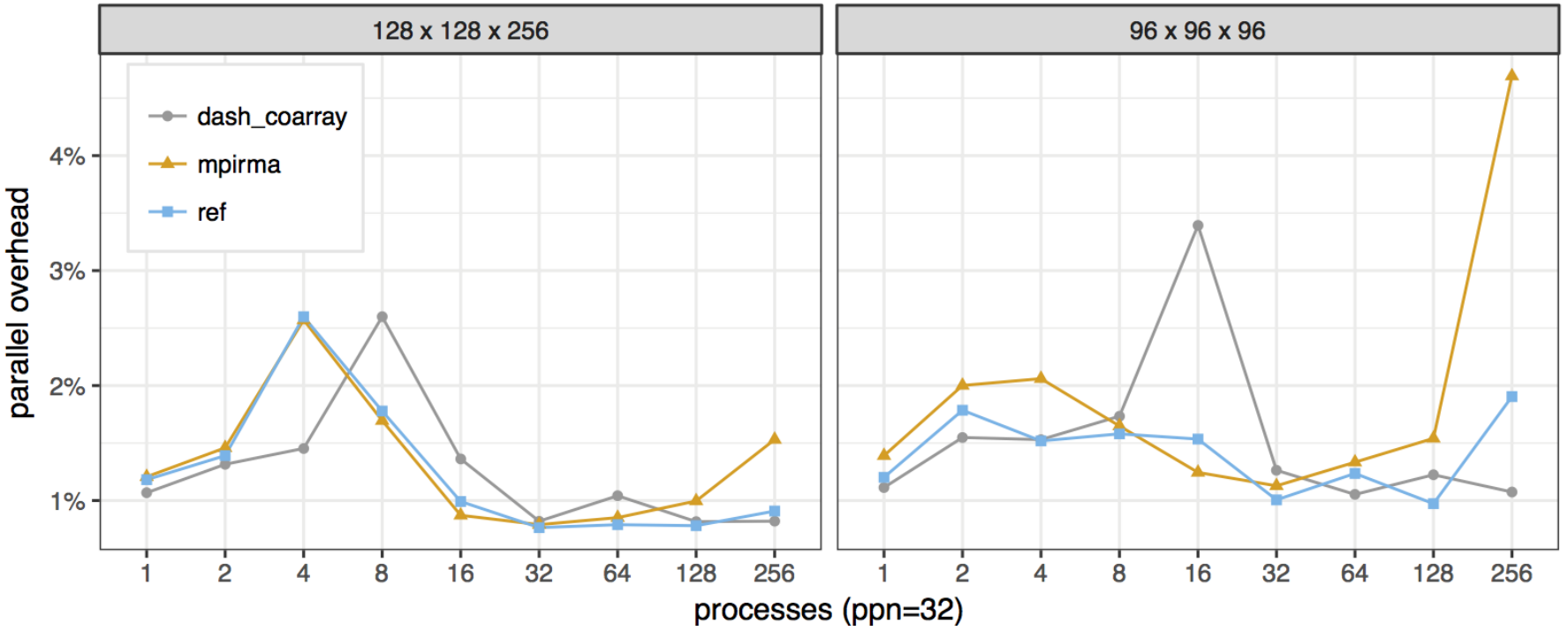
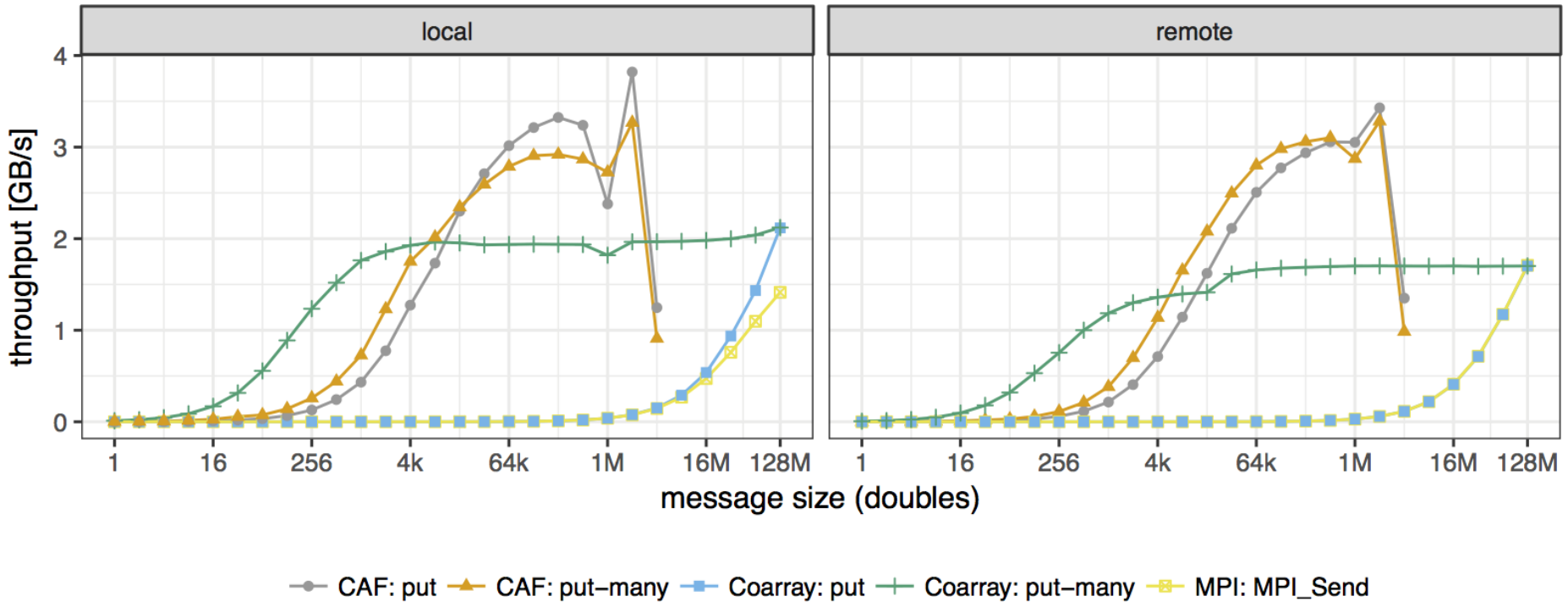


Evaluation

- CAF-Bench (SuperMUC - IntelMPI)
  - Simulate communication patterns
  - Single element / ranges | Blocked / Async
  - Local / remote (various locality domains)



Summary

- CAF interface as C++ library
- Many shortcomings of CAF fixed
- Good integration in DASH
- Highly scalable with good performance

- Major challenges during the project
  - Full-stack guarantees (memory, progress)
  - Minimizing overhead

Acknowledgements

DASH on GitHub:
https://github.com/dash-project/dash

Coarray part of release 0.3.0
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