# Towards a matrix-oriented strided interface in OpenSHMEM

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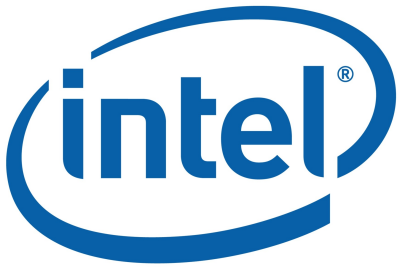

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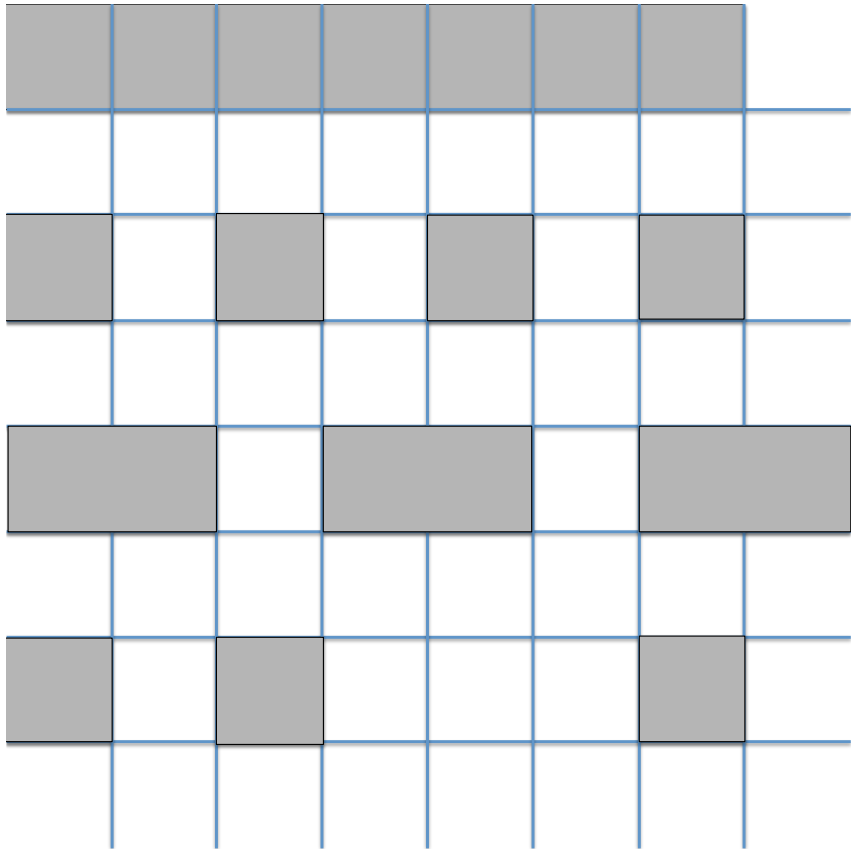
- Hanlon's Razor.

# Types of regular/direct data

- Contiguous
- Element Strided
- Block Strided
- Indexed



# Data types in APIs

- **Contiguous** - MPI, SHMEM, ARMCI, etc.
- **Element Strided** - MPI, SHMEM, ARMCI, etc.
- **Block Strided** - MPI, ~~SHMEM~~, ARMCI, etc.
- **Indexed** - MPI, ~~SHMEM~~, ARMCI, etc.

Where does it make sense to stop?

Why does SHMEM have element strided?

# Hardware considerations

- **Contiguous** - Obvious.
- **Element Strided** - Sub-packet elements bad.
- **Block Strided** - Amortize call overhead.
- **Indexed** - Where to stop with descriptors?

If SHMEM message-rate is high enough, all we need to do is exceed packet size.

**Except we have to wait on local completion for every call...**

# Datatypes vs. nonblocking

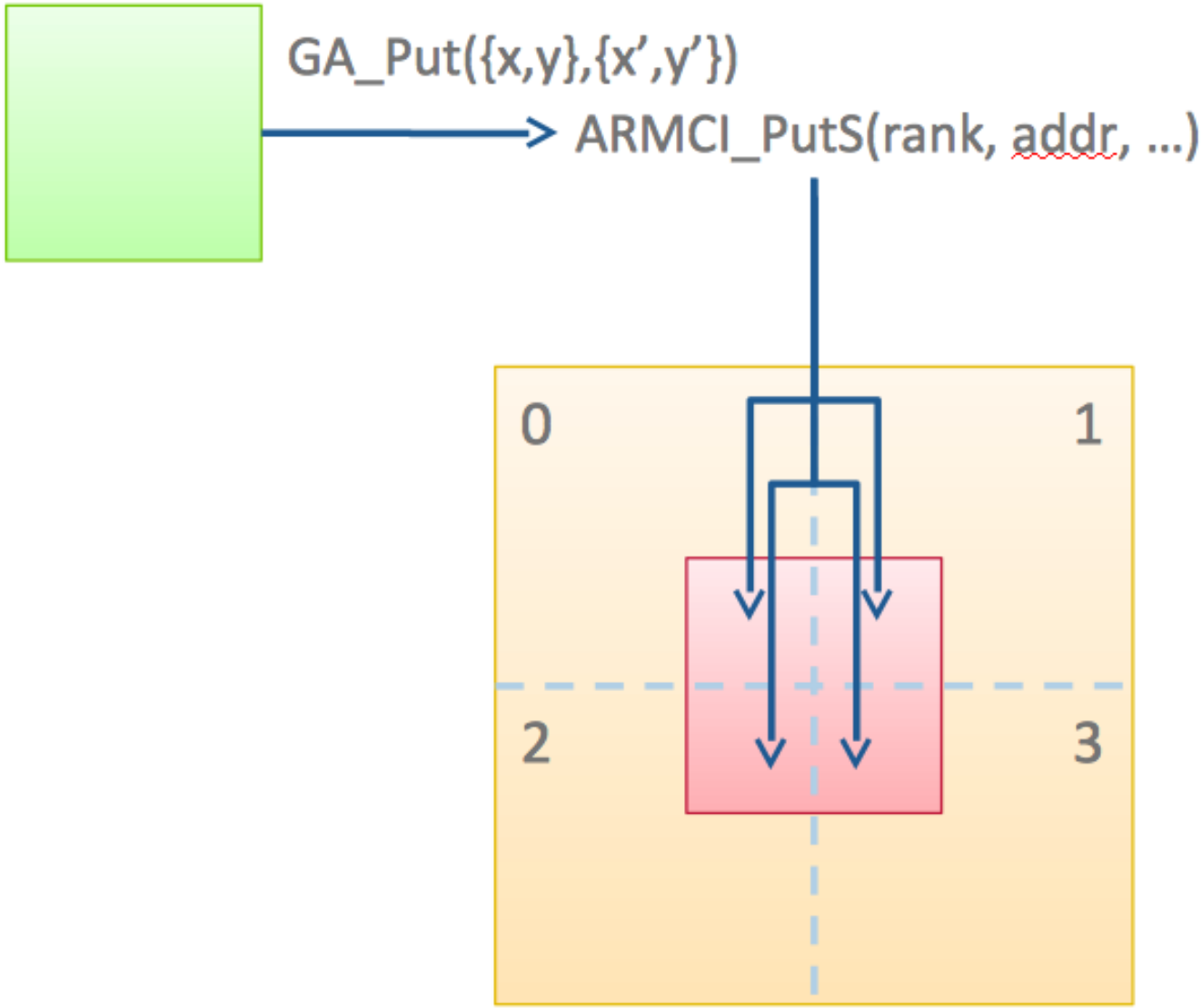
Nonblocking SHMEM Put and Get would seriously improve the situation, but one still has $O(N_{\mathrm{MIN}(rows,cols)})$ function calls for a submatrix.

Some networks (e.g. Cray Aries) don't let us inject an arbitrary number of nonblocking operations without a synchronization call.

Linear algebra entails a particular data semantic that deserves first-class treatment in the API.

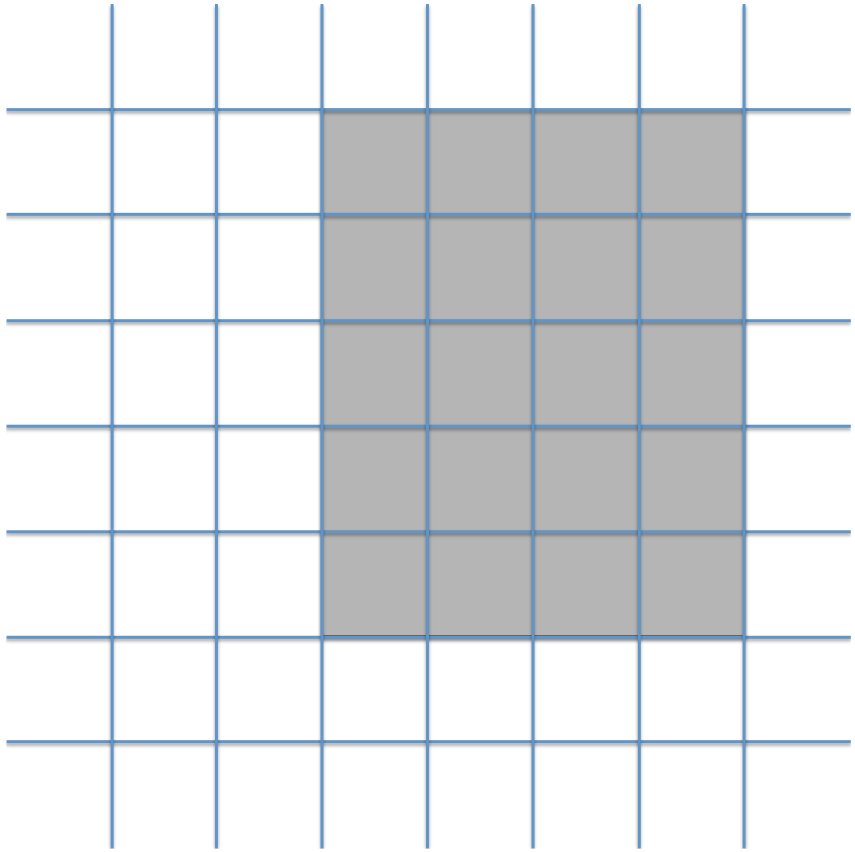
Runtime systems can do more with more...

# Global Arrays - (sub)matrices are first-class objects

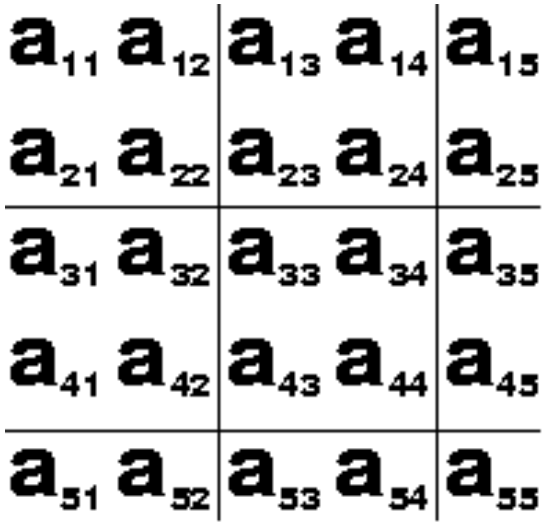


# Submatrix communication

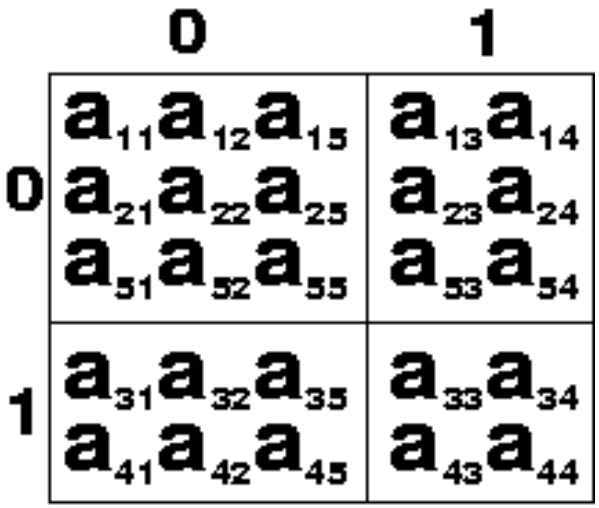
- Algorithmic block size may not match data block size.
- Data access pattern may change over the lifetime of object.
- If embedding complex data in a matrix, may want only one component.



# ScaLAPACK block cyclic



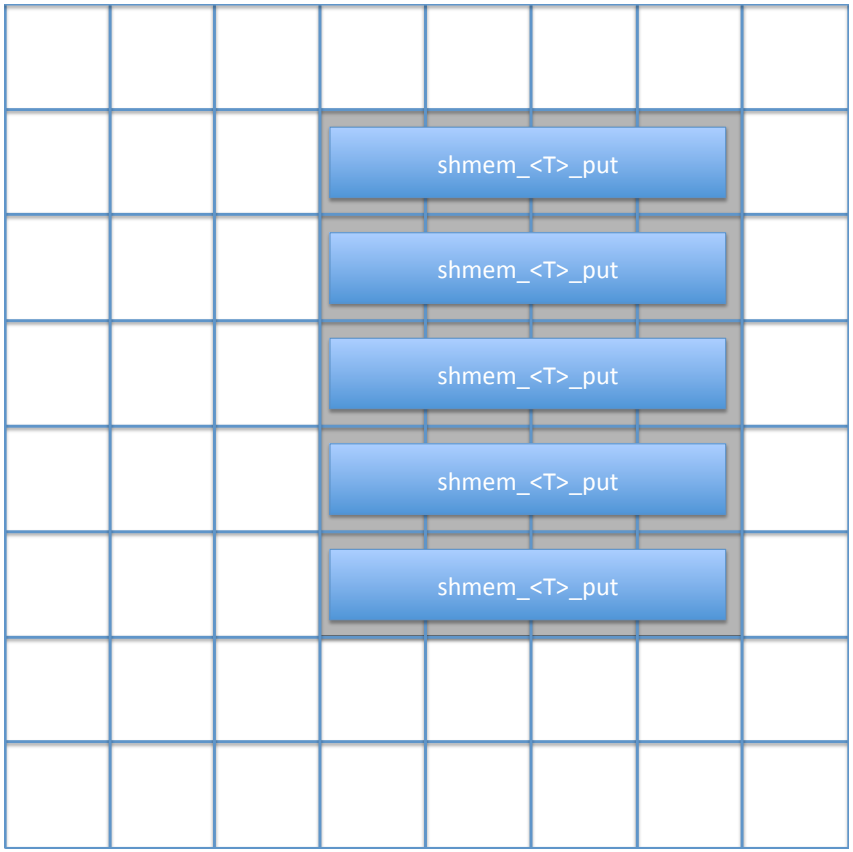

5 x 5 matrix partitioned in 2 x 2 blocks




2 x 2 process grid point of view

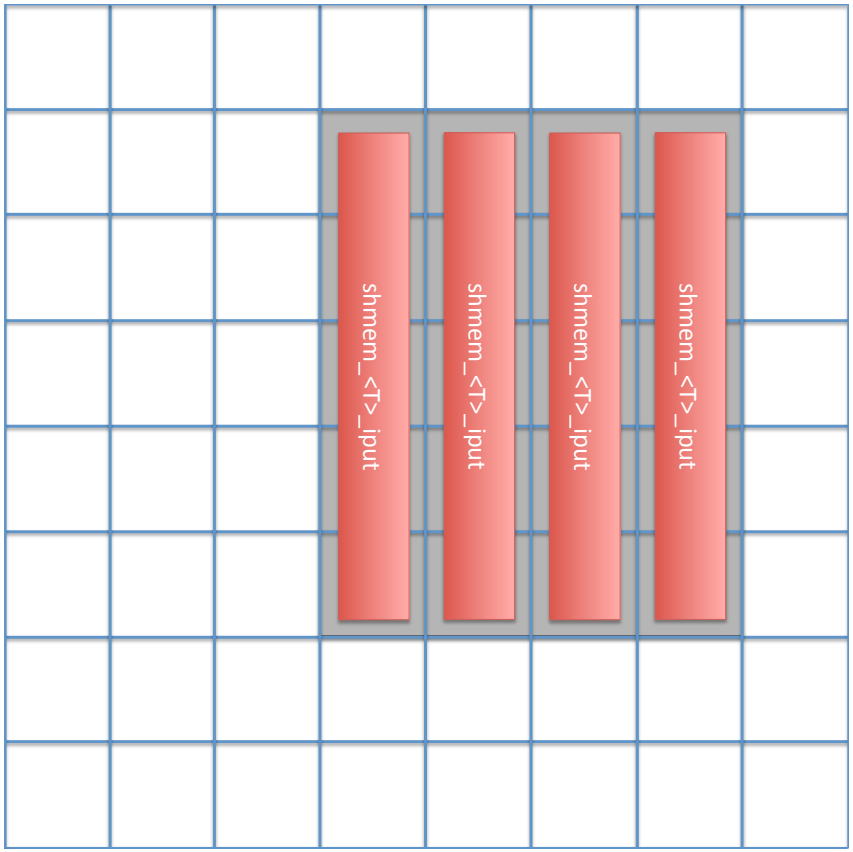
# Submatrix as many contiguous chunks

- Map subarray to vector of contiguous vectors.
- $O(N_{rows})$ function calls.
- Block until buffer accessible $\rightarrow$ bad for Get.
- This method far more reasonable with nonblocking.
- Efficient for $N_{cols} > N_{rows}$.



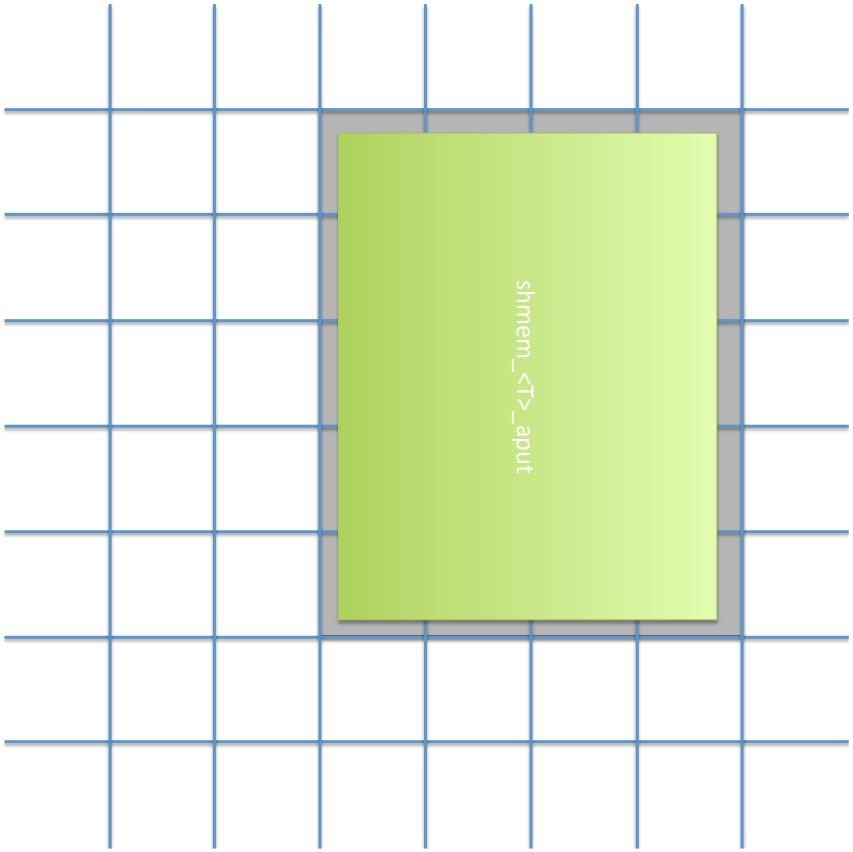
# Submatrix as many strided vectors

- Map subarray to vector of strided vectors.
- $O(N_{cols})$ function calls.
- Blocking bad here too.
- Strided touches same cache line repeatedly.
- Efficient for $N_{cols} < N_{rows}$?



# Submatrix communication

- One blocking function call.
- Runtime knows everything about data transfer.
- Maps directly to dense linear algebra semantics.



# Reference implementation

```
void shmemx_double_aput(double * dest, const double * src,
                        ptrdiff_t dstr, ptrdiff_t sstr,
                        size_t blksz, size_t blkct, int pe)
{
  double       *dtmp = dest;
  const double *stmp = src;
  if (blksz<blkct) /* may require tuning */ {
    for (size_t i=0; i<blksz; i++) {
      shmem_double_iput(dtmp, stmp, dstr, sstr, blkct, pe);
      dtmp++; stmp++;
    }
  } else {
    for (size_t i=0; i<blkct; i++) {
      shmem_double_put(dtmp, stmp, blksz, pe);
      dtmp += dstr; stmp += sstr;
    }
  }
}
```

# Optimized implementation

```
void shmemx_double_aput(double * dest, const double * src,
                        ptrdiff_t dstr, ptrdiff_t sstr,
                        size_t blksz, size_t blkct, int pe)
{
  int maxnbi = DMAPP_DEF_OUTSTANDING_NONBLOCKING/2;
  double       *dtmp = dest;
  const double *stmp = src;
  /* skipping iput implementation */
  for (size_t i=0; i<blkct; i++) {
      dmapp_put_nbi(dtmp, _sheap, pe, (double*)stmp,
                    blksz, DMAPP_QW);
      if (i && i%maxnbi==0) dmapp_gsync_wait();
      dtmp += dstr; stmp += sstr;
  }
  if (blkct%maxnbi!=0) dmapp_gsync_wait();
}
```

# Other optimized implementations

- Sreeram Potluri and I wrote a highly optimized implementation for IBM® Blue Gene/P* in DCMF* that packed up to packet granularity (active-message unpacking) and otherwise injected directly.
- PAMI* (Blue Gene/Q*, PERCS*) has a datatype engine that can in theory map to network DMA scatter-gather.
- Surely there is something for InfiniBand®...
- OSHMPI (MPI-3 RMA as conduit) maps directly to subarray type.
- Any one-sided API that has nonblocking should benefit.

*Other names and brands may be claimed as the property of others.

# Performance Results

- The performance improvement over a straightforward implementation on Blue Gene/P was huge. We never compared against SHMEM-like implementation and the hardware is all scrap now ☹
- Cray® XC30 tests at small scale show modest improvement. For small jobs (especially within an Aries quartet) without any contention, the benefit of nonblocking is not too large.

It will be a lot easier to gather performance data by mapping ARMCI to OpenSHMEM since we already have all the performance benchmarks oriented at Global Arrays usage.

# Acknowledgements

Jim Dinan (Intel) for an uncountable number of discussions of one-sided in SHMEM, ARMCI...

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