COLLECTIVE ALGORITHMS FOR SUB-COMMUNICATORS

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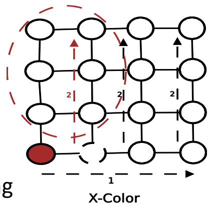
Collective communication over a group of processors is an integral and time consuming component in many high performance computing applications.
We present novel techniques to perform collective operations over a subset of processors in a torus network obtaining over 5x speedup over current best.

Motivation

- **Why Collectives?**
  Performance of MPI collectives is critical for improved scalability and efficiency, for large messages network contention need to be avoided
- **Why Sub-communicators?**
  Many applications involve collective operations on sub partitions (i.e., sub-communicators in MPI).
- **Why a new approach?**
  The algorithms developed so far are not contention free for a random sub-communicator

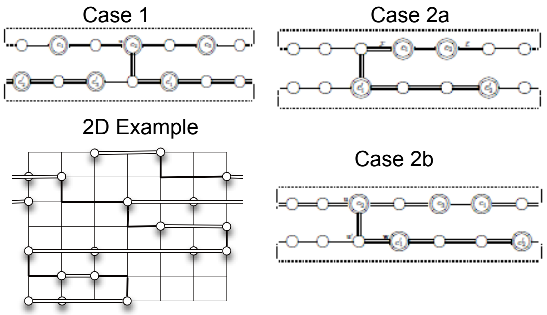
Common Sub-communicators

- **Random Communicator**
  Our algorithm achieves a single link throughput performance
- **Single Missing Node**
  The tree is constructed using a pseudo root that is at least one hop away from the missing node in every dimension. The missing node is by-passed during the tree construction and the directions of the links are adjusted according to the user specified root.



- **Random subset of parallel planes**
  Phase 1 and 2 proceeds as described in [1] assuming that the missing planes are in the Z direction. For phase 3, the data is transferred along the Z dimension, with the missing planes in Z dimension being bypassed to transfer the data to the nodes in next 2D plane.

[1] Faraj et.al., MPI collective communications on the Blue Gene/P supercomputer: algorithms and optimizations". In ICS 2009



Algorithm

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1. Let $y_1, y_2, \ldots, y_r$ be a sequence of $y$-coordinates that
   contain c-nodes such that the $y$-distance between two
   consecutive $y$-coordinates in this sequence $\leq d_y/2$,
   i.e., $(y_{i+1} - y_i) \mod d_y \leq d_y/2$ for all $1 \leq i < r$.
   Let $\ell(i)$ denote the line corresp. to $y_i$ for $1 \leq i \leq r$.

2. Let $< c_1, .., c_m >$ be the chain of c-nodes in line $\ell(1)$.
   Connect the c-nodes in the chain in a straight line.

3. For $i = 1$ to $r - 1$ do
   Connect $\ell(i)$ to $\ell(i+1)$ based on the following cases:

   Case 1: $\ell(i+1)$ does not have a gap of $d_x/2+1$
   a. Select any c-node in $\ell(i)$, say $u$, as the connector.
   b. Progress down from $u$ to $\ell(i+1)$ and then move
      towards right in $\ell(i+1)$, say $c_1'$
   c. Form a chain in $\ell(i+1)$ starting with $c_1'$ and cover
      all the c-nodes in $\ell(i+1)$ proceeding in the same
      direction.

   Case 2: $\ell(i+1)$ has a gap of $d_x/2+1$
      Let $< c_1, c_2, \ldots, c_m >$ be the chain of $\ell(i)$
      where $c_1$ is the head node and $c_m$ is the tail node

      Case 2(a): there exists a c-node, $u$, in $\ell(i)$
        that is directly above a node not contained in
        the chain of $\ell(i+1)$
      a. Progress down from $u$ to $\ell(i+1)$ and then
      move towards the closest node in $\ell(i+1)$
      c. Form a chain starting with this node and cover
         all the c-nodes in $\ell(i+1)$ proceeding in the
         same direction.

      Case 2(b): All c-nodes in $\ell(i)$ are above nodes
        contained in the chain of $\ell(i+1)$
        Let $u \in \{c_1, c_m\}$ be a node that has an edge
        adjacent to it in $\ell(i)$ that is not used in the tree
      a. Progress from $u$ in the direction of the unused
         edge till you reach above the first or last
         c-node of the chain of $\ell(i+1)$
      b. Progress down to the c-node of $\ell(i+1)$
      c. Form a chain starting with this node and cover
         all the c-nodes in $\ell(i+1)$
```

Results

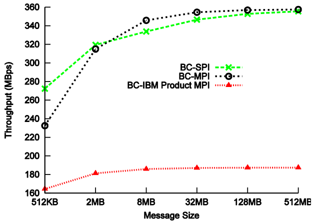
All the experiments were performed on Blue Gene/P.

Implemented versions

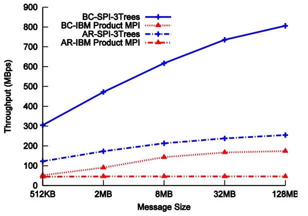
1. Optimized version which uses lower level API (SPI)
2. MPI version by modifying the MPI stack

Results

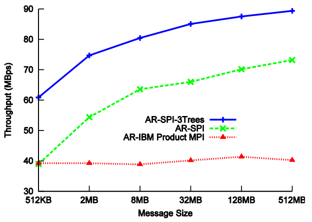
Our MPI implementation obtains a speedup of 1.5-3x over IBM's product MPI for a single random communicator. Our SPI implementation achieves a speedup of 1.7-5.8x for special sub-communicators. For multiple sub-comms., we observe a speedup of 1.6-2.6x.



Broadcast on sparse random sub-communicator



Broadcast and Allreduce on missing planes



Simultaneous Allreduce on multiple sub-communicators