Kommunikation in HPC-Clustern

Communication/Computation Overlap in MPI

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Outline

1 Motivation

2 Current Research
- Optimized Collective Operations
- Non-blocking Collective Operations
- Example

Motivation

- Optimize run-time of (highly) parallel applications
- Use powerful parallel libraries that
- Support aggressive **overlap of communication and computation**
- A typical library (e.g. ScaLapack) is based on **MPI**/BLACS

Motivation

- Overlap is enabled by **non-blocking MPI** operations
- Until now only non-blocking Point-to-Point operations
- **(Non-blocking) MPI collectives** could take advantage of special HW support of the underlying network

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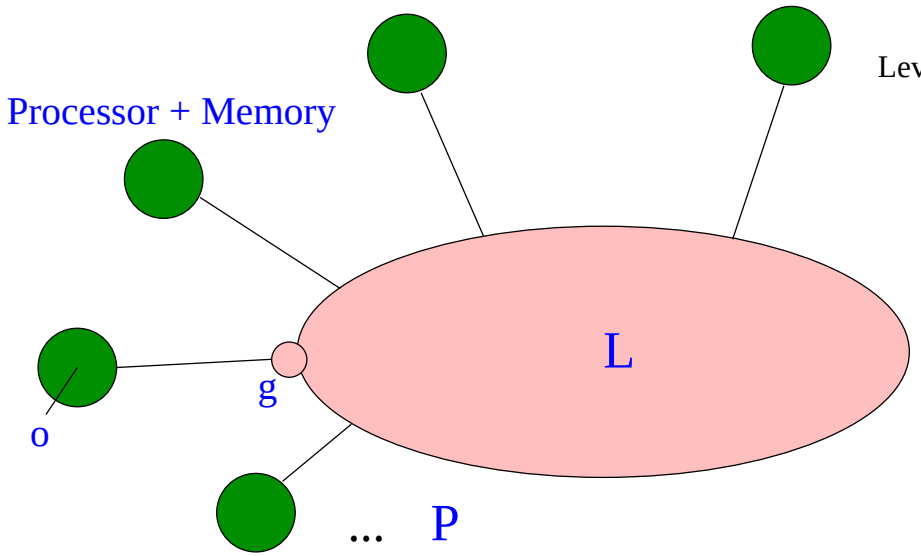
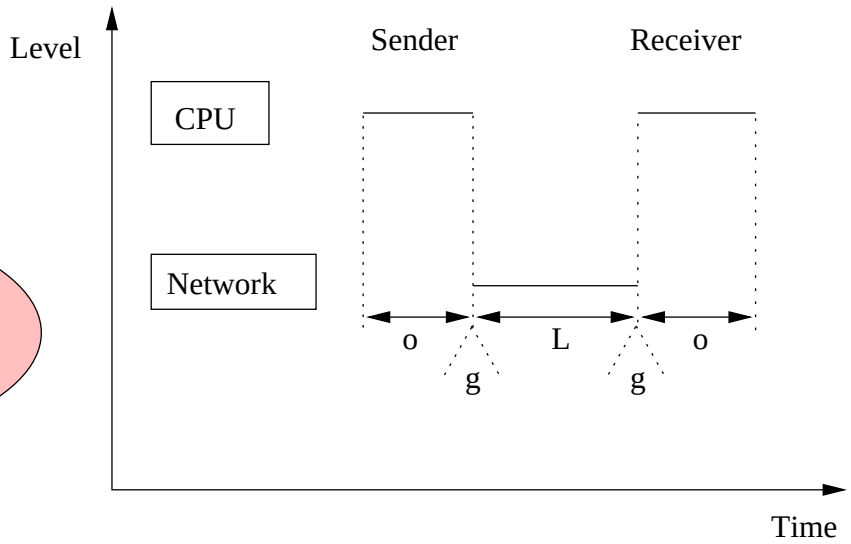
Our Current Research

- Tuning collective communication routines **e.g. optimized MPI_Barrier()**
- Targeting at special support of the underlying network (**InfiniBand's** multicast, atomic ops, RDMA)
- Implementing **Non-blocking Collectives** within the framework of **Open MPI** (”coll” component)

An Optimized InfiniBand Barrier

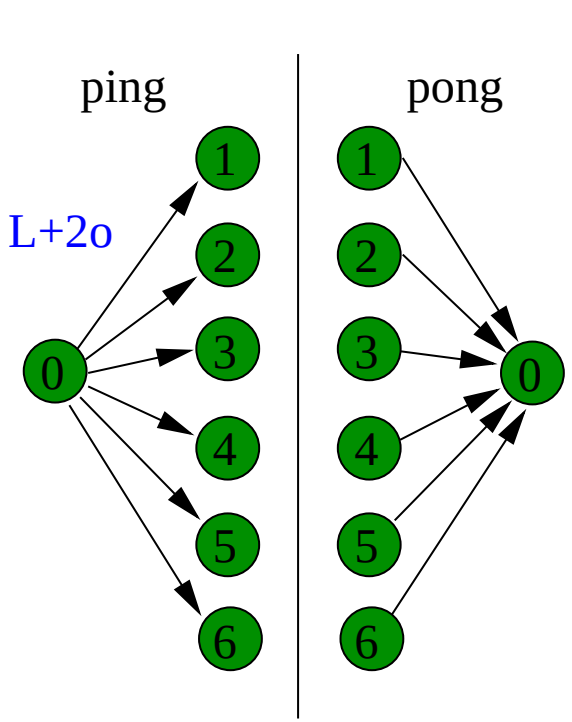
- The LogP model abstracts for giving a rough communication performance estimation

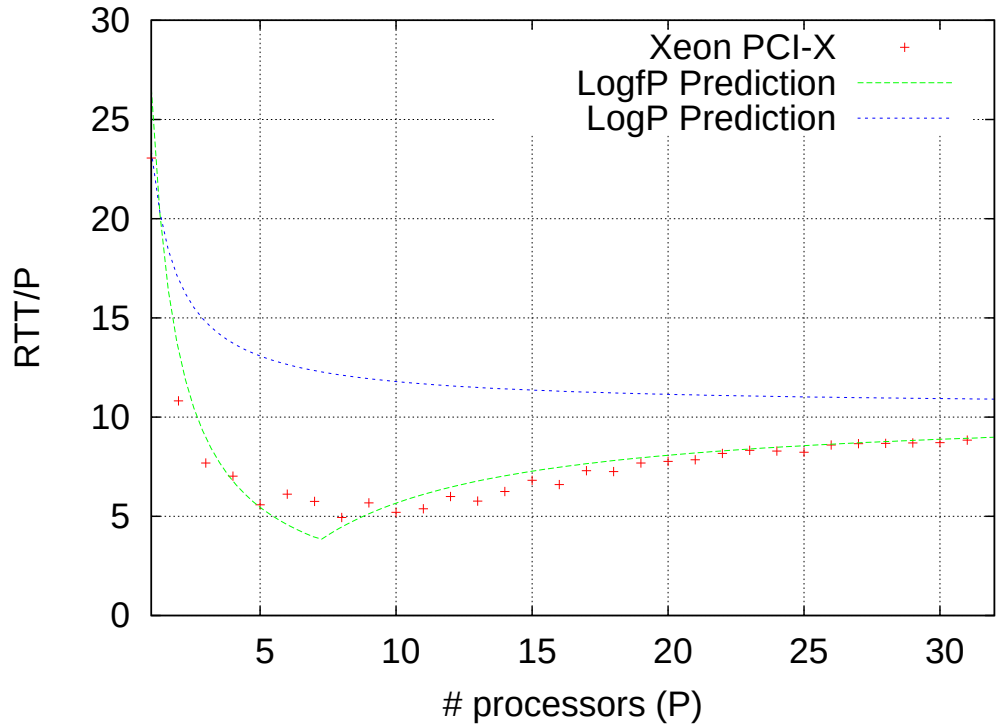




An Optimized InfiniBand Barrier

- But 1:P-P:1 benchmark reveals an implicite parallelism for InfiniBand



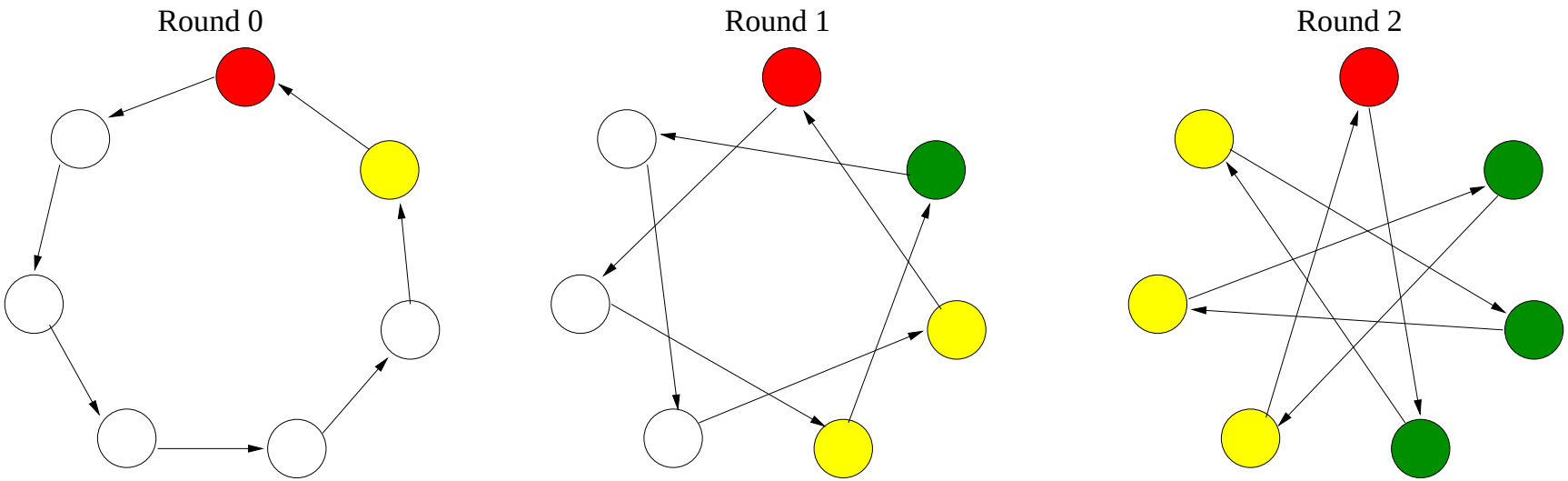


An Optimized InfiniBand Barrier

- Thus, f is introduced (the first f small messages are essentially for free)
  - T. Hoefler et. al.: *L*ogfP - A Model for small Messages in InfiniBand
- For the first f messages it seems that there are f ports - instead of one
- All current algorithms have been modeled and optimized for single-port nodes
- The **Dissemination Barrier Algorithm** works best for single ported nodes (proven with LogP)
- The idea came up to create an **n-way Dissemination Barrier**

An Optimized InfiniBand Barrier

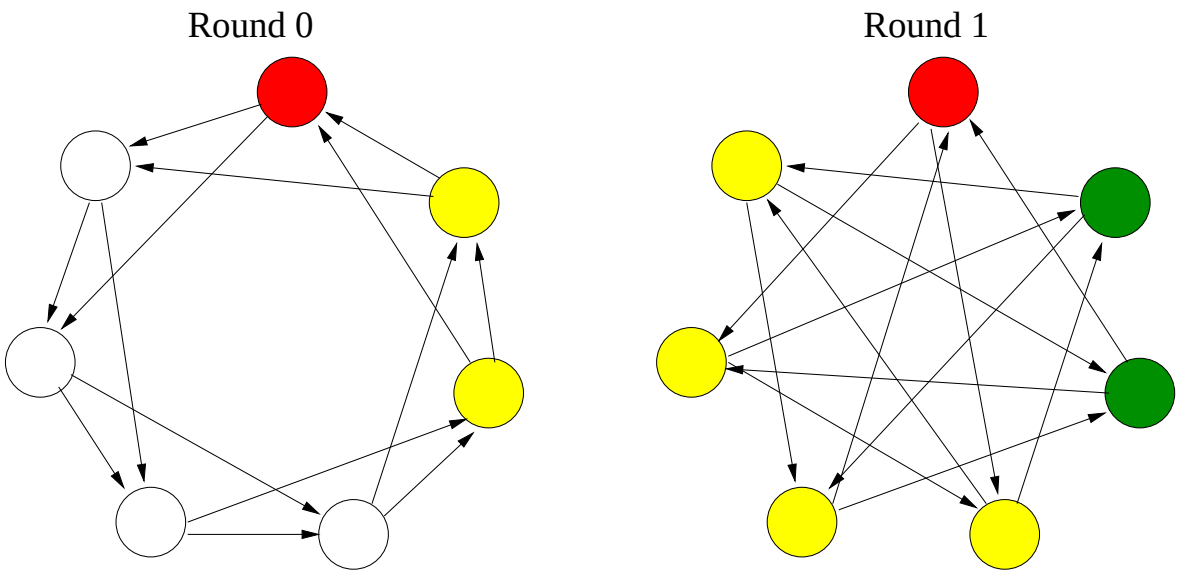
- The Dissemination Barrier Algorithm



- run-time $O(log_2 P)$

An Optimized InfiniBand Barrier

- The n-way Dissemination Barrier Algorithm



- run-time $O(log_{n+1}P)$
  - T. Hoefler et. al.: *A*n optimal Synchronization Algorithm for Multi-Port Networks
  - T. Hoefler et. al.: *F*ast Barrier Synchronization for InfiniBand

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Helping to Answer

- Overlapping Comm/Comp programming style (threads) too complex
- What is the tradeoff of performance and programming effort?
- *J.B. White: "...programming for overlap may be of little benefit for synchronous applications in general. Many current MPI implementations -all those tested here- do not support the required level of overlap. The additional development effort and code complexity required to program for overlap seems unjustified..."*
- We contribute to answer by **implementing non-blocking collectives** in the context of a **real application (Abinit)**!

Its not just Performance - Why Collectives?

- Gorlach, '04: "Send-Receive Considered Harmful"
- $\Leftrightarrow$ Dijkstra, '68: "Go To Statement Considered Harmful"

point to point:

```
if ( rank == 0) then
   call MPI_SEND(...)
else
   call MPI_RECV(...)
end if
```

vs. collective:

```
call MPI_GATHER(...)
```

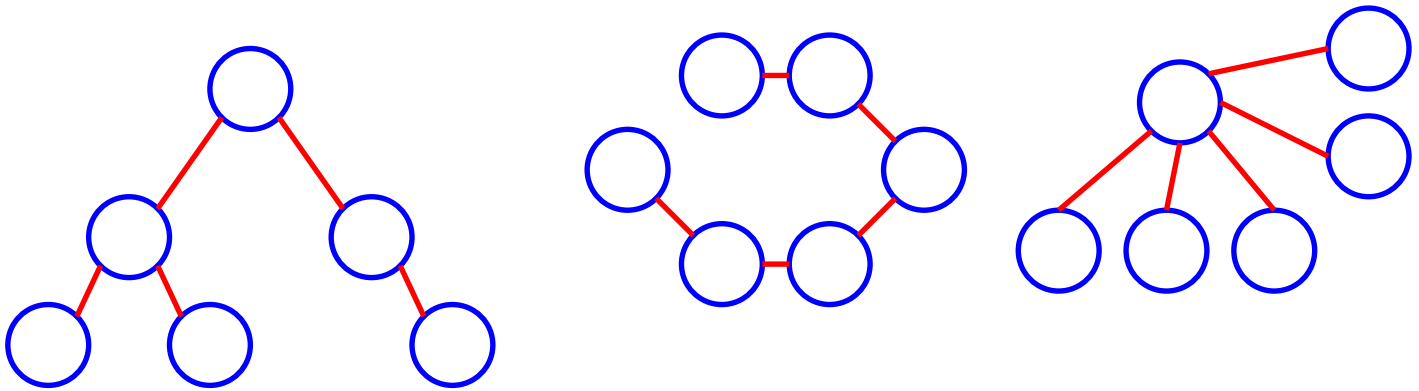
cmp. math libraries vs. loops

Putting Everything Together

- non blocking collectives?
- JoD mentions ”split collectives”
- example:
  - MPI_Bcast_begin(...)
  - MPI_Bcast_end(...)
- no nesting with other colls
- very limited
- not in the MPI-2 standard
- votes: 11 yes, 12 no, 2 abstain

Why non blocking Collectives

- many collectives synchronize unneccessary
- scale with $O(log_2 P)$ sends
- wasted CPU time: $log_2 P \cdot 2L$
  - Fast Ethernet: L = 50-60
  - Gigabit Ethernet: L = 15-20
  - InfiniBand: L = 2-7
  - $1\mu s \approx$ 4000 FLOPs on a 2GHz Machine



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Pseudocode Overlap

```
do ....
  ! send communication buffer
  MPI_Isend(buffer_comm, ..., reg, ...)

  ! do useful work
  do_work(buffer_work)

  ! finish communication
  MPI_Wait(req, ...)

  ! swap the buffers
  buffer_tmp = buffer_comm
  buffer_comm = buffer_work
  buffer_work = buffer_tmp
enddo
```

Linpack Problem

- solves $Ax = b$ with $A = PLU$ decomposition
- row partial pivoting
- A and b are given
- Gauss Algorithm for A
- $O(n^3)$ FP operations
- applied to b (no need to store P or L)
- solution by backwards substitution of U
- our example assumes column-wise distribution
- block distribution more complicated

Example - Linpack Problem - traditional

```
do k=1,n,1 ! loop over columns
  if (IHaveColumn(k)) max = findMaxColumn(k)
  MPI_Bcast(max);
  exchangeRow(max,k)
  do i=k+1,n,1 ! loop over rows
    if (IHaveColumn(k)) div = A(i+1,k) / A(k,k)
    MPI_Bcast(div)
    do j=k+1,n,1 ! essentially DAXPY
      A(i,j) = A(i,j) - div * A(k,j)
    enddo
    b(i) = b(i) - div * b(k)
  enddo
enddo
```

Example - Linpack Problem - non-blocking Collectives

```
do k=1,n,1 ! loop over columns
  if (IHaveColumn(k+1)) nextmax = findMaxColumn(k+1)
  MPI_Ibcast(nextmax, h1);
  exchangeRow(max,k)
  do i=k+1,n/p,1 ! loop over rows
    if (IHaveColumn(k)) nextdiv = A(i+1,k) / A(k,k)
    MPI_Ibcast(nextdiv, h2)
    do j=k+1,n,1 ! essentially DAXPY
      A(i,j) = A(i,j) - div * A(k,j)
    enddo
    b(i) = b(i) - div * b(k)
    MPI_Wait(h2); div = nextdiv
  enddo
  MPI_Wait(h1); max = nextmax
enddo
```