Lecture 24: Buffering and Message Protocols

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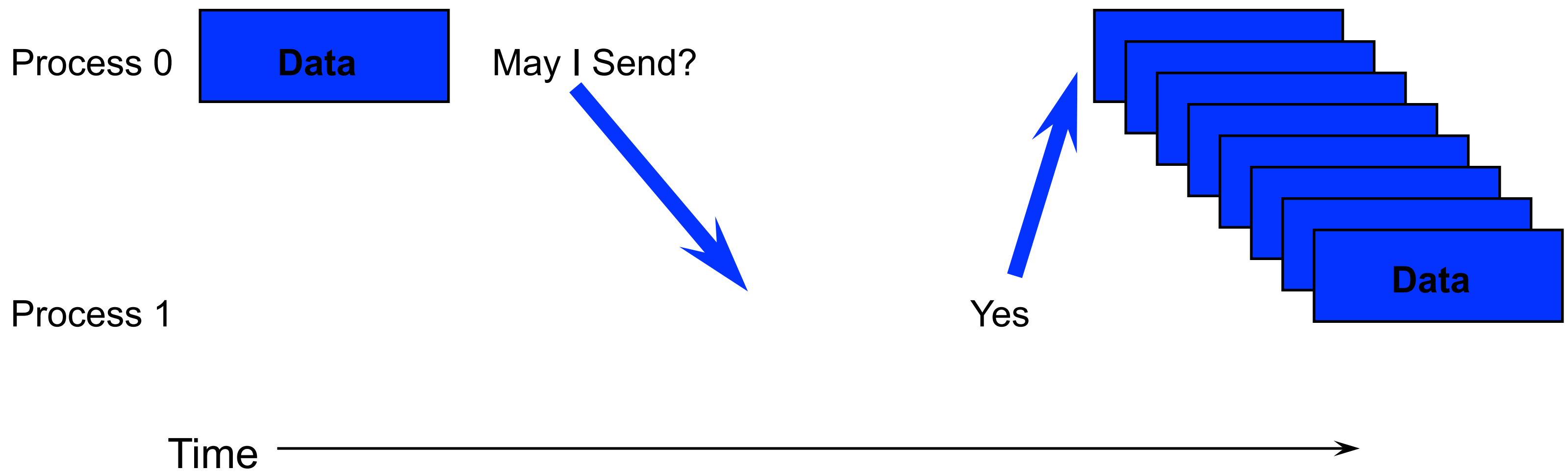
More On Communication

- How does the MPI implementation orchestrate the communication of data from one process to another?

What is message passing?

- Data transfer plus synchronization



- Requires cooperation of sender and receiver
- Cooperation not always apparent in code

Quick Review of Message Passing Terms in MPI

- Basic terms
  - nonblocking - Operation does not wait for completion
  - synchronous - Completion of send *requires* initiation (but not completion) of receive
  - ready - *Correct* send requires a matching receive
  - asynchronous - communication and computation take place simultaneously, ***not*** an MPI concept (implementations *may* use asynchronous methods)

Message protocols

- Message consists of "envelope" and data
  - Envelope contains tag, communicator, length, source information, plus impl. private data
- Short
  - Message data (message for short) sent with envelope
- Eager
  - Message sent assuming destination can store
- Rendezvous
  - Message not sent until destination oks

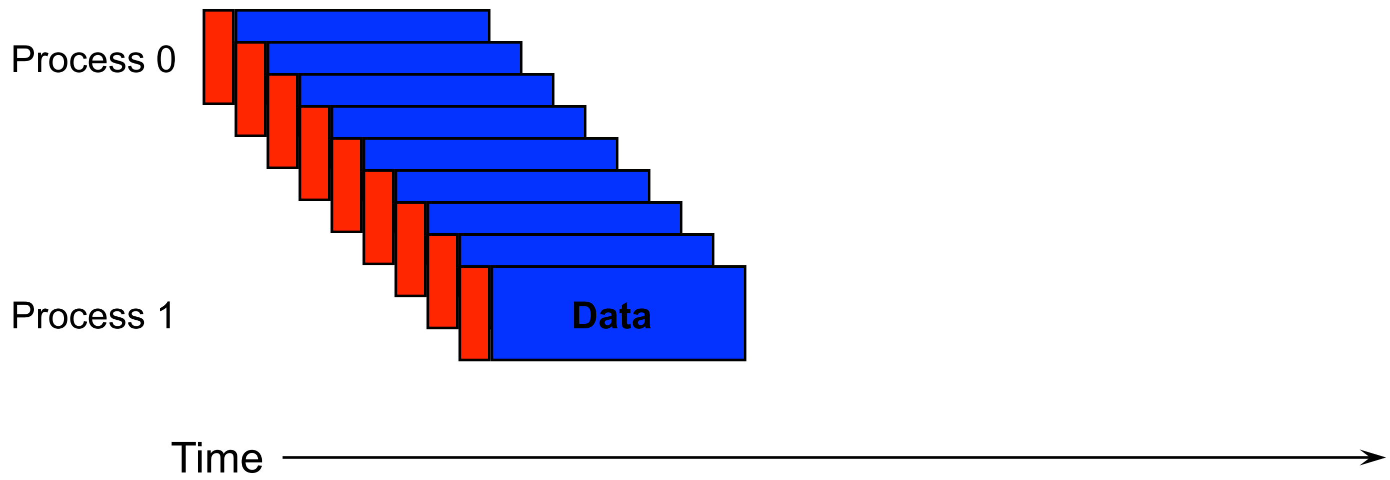
MPI on Distributed Shared Memory Systems

- Message passing is a good way to use distributed shared memory (DSM) machines because it provides a way to express memory locality.
- Put
  - Sender puts to destination memory (user or MPI buffer). Like Eager.
- Get
  - Receiver gets data from sender or MPI buffer. Like Rendezvous.
- Short, long, rendezvous versions of these

Message Protocol Details

- Eager not Rsend, rendezvous not Ssend resp., but related
- User versus system buffer space
- Packetization
- Collective operations
- Datatypes, particularly non-contiguous
  - ♦ Handling of important special cases
    - Constant stride
    - Contiguous structures

Eager Protocol



- Data delivered to process 1
  - ♦ No matching receive may exist; process 1 must then buffer and copy.

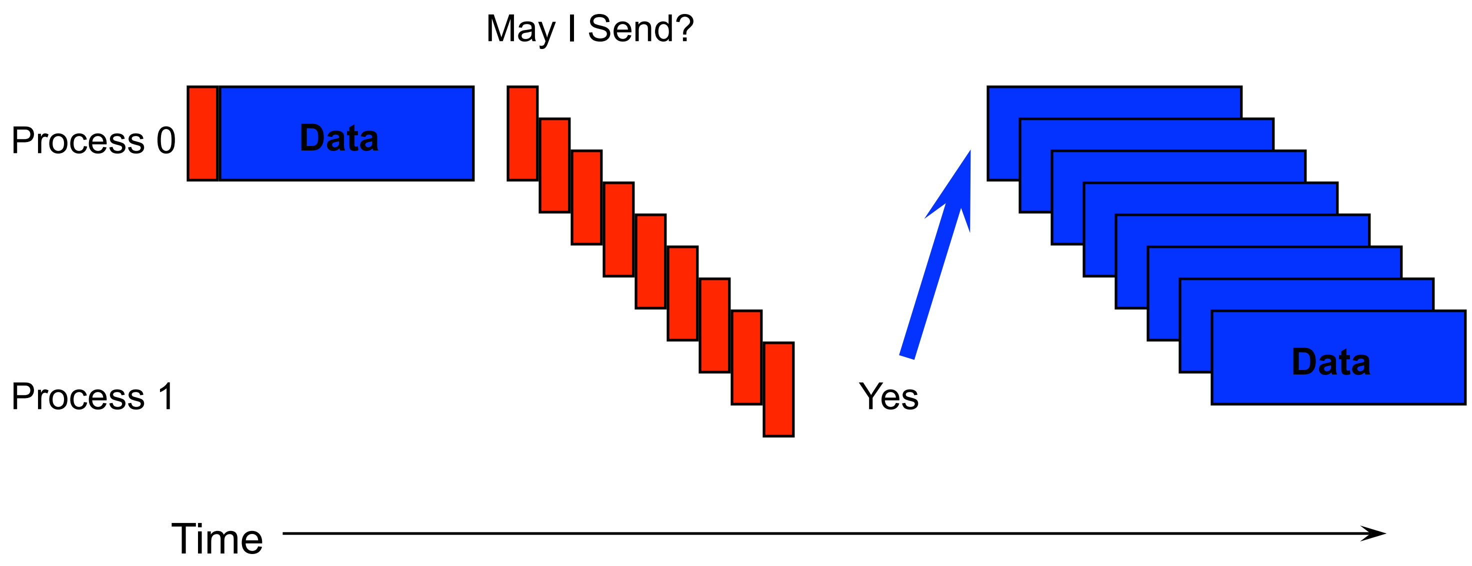
Eager Features

- Reduces synchronization delays
- Simplifies programming (just MPI_Send)
- Requires significant buffering
- May require active involvement of CPU to drain network at receiver's end
- May introduce additional copy (buffer to final destination)

How Scalable is Eager Delivery?

- Buffering must be reserved for arbitrary senders
- User-model mismatch (often expect buffering allocated entirely to “used” connections).
- Common approach in implementations is to provide same buffering for all members of MPI_COMM_WORLD; this is optimizing for non-scaleable computations
- Scalable implementations that exploit message patterns are possible (but not widely implemented)

Rendezvous Protocol



- Envelope delivered first
- Data delivered when user-buffer available
  - Only buffering of envelopes required

Rendezvous Features

- Robust and safe
  - (except for limit on the number of envelopes…)
- May remove copy (user to user direct)
- More complex programming (waits/tests)
- May introduce synchronization delays (waiting for receiver to ok send)

Short Protocol

- Data is part of the envelope
- Otherwise like eager protocol
- May be performance optimization in interconnection system for short messages, particularly for networks that send fixed-length packets (or cache lines)

User and System Buffering

- Where is data stored (or staged) while being sent?
  - ♦ User's memory
    - Allocated on the fly
    - Preallocated
  - ♦ System memory
    - May be limited
    - Special memory may be faster

Implementing MPI_Isend

- Simplest implementation is to always use rendezvous protocol:
  - MPI_Isend delivers a request-to-send control message to receiver
  - Receiving process responds with an ok-to-send
    - May or may not have matching MPI receive; only needs buffer space to store incoming message
  - Sending process transfers data
- Wait for MPI_Isend request
  - wait for ok-to-send message from receiver
  - wait for data transfer to be complete on sending side

Alternatives for MPI_Isend

- Use a short protocol for small messages
  - No need to exchange control messages
  - Need guaranteed (but small) buffer space on destination for short message envelope
  - Wait becomes a no-op
- Use eager protocol for modest sized messages
  - Still need guaranteed buffer space for both message envelope and eager data on destination
  - Avoids exchange of control messages

Implementing MPI_Send

- Can't use eager always because this could overwhelm the receiving process

```
if (rank != 0) MPI_Send( 100 MB of data )
else receive 100 MB from each process
```

- Would like to exploit the blocking nature (can wait for receive)
- Would like to be fast
- Select protocol based on message size (and perhaps available buffer space at destination)
  - Short and/or eager for small messages
  - Rendezvous for longer messages

Implementing MPI_Rsend

- Just use MPI_Send; no advantage for users
- Use eager always (or short if small)
  - even for long messages

Choosing MPI Send Modes

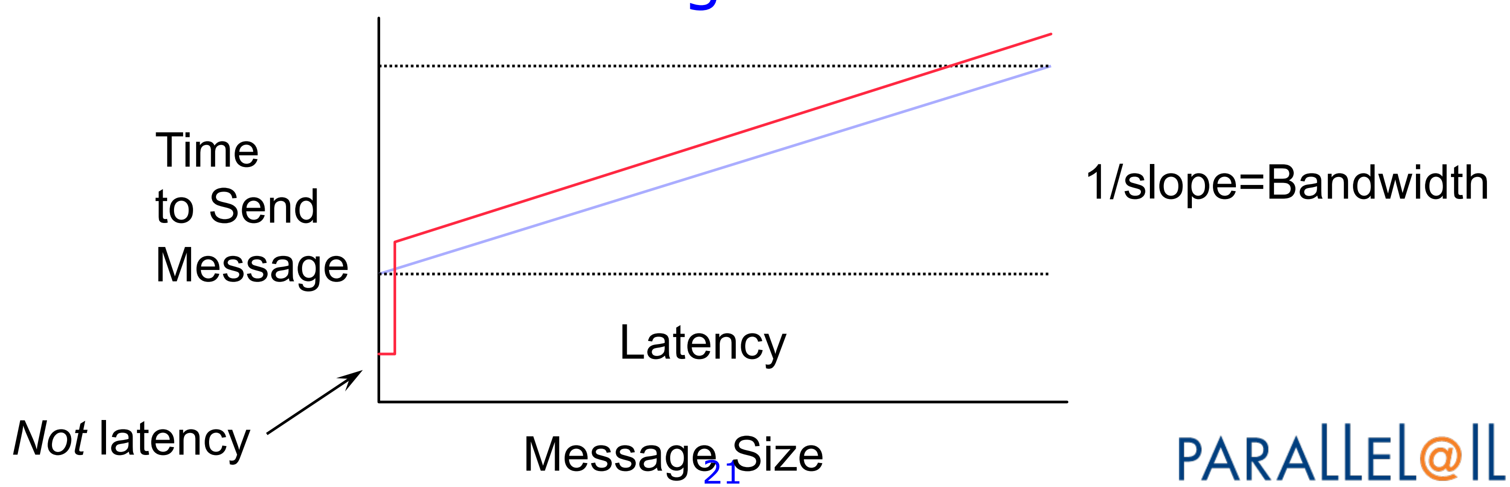
- No perfect choice. However:
  - ♦ Eager is faster than rendezvous until
    - Data is unexpected: 2*latency is smaller than the time to copy from buffer
  - ♦ Ready can force Eager, but requires prepost of receive
    - Best when data is long but not too long (measured in terms of s/r)
  - ♦ Synchronous good when MPI implementation has inadequate flow control and messages are large

Latency and Bandwidth

- Simplest model $s + r\, n$
- s includes both hardware (gate delays) and software (context switch, setup)
- r includes both hardware (raw bandwidth of interconnection and memory system) and software (packetization, copies between user and system)
- Head-to-head and pingpong values may differ

Interpreting Latency and Bandwidth

- Bandwidth is the inverse of the slope of the line
  time = latency + (1/rate) size_of_message
- For performance estimation purposes, latency is the limit($n \rightarrow 0$) of the time to send n bytes
- Latency is sometimes described as "time to send a message of zero bytes". This is true *only* for the simple model. The number quoted is sometimes misleading.



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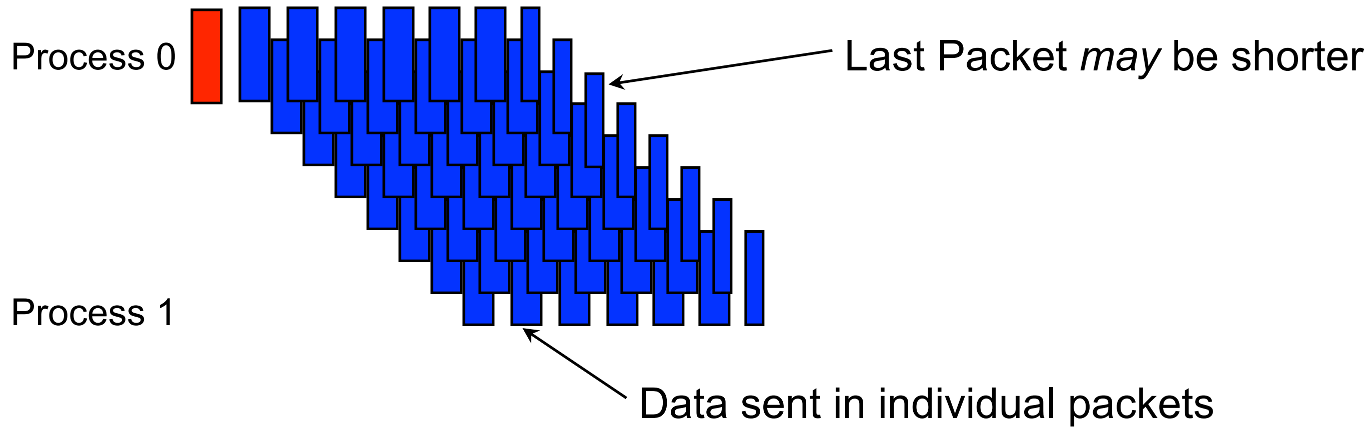
Try It Yourself: Timing MPI Operations

- Estimate the latency and bandwidth for some MPI operation (e.g., Send/Recv, Bcast, Ssend/Irecv-Wait)
  - Make sure all processes are ready before starting the test
  - How repeatable are your measurements?
  - How does the performance compare to the performance of other operations (e.g., memcpy, floating multiply)?

Packetization

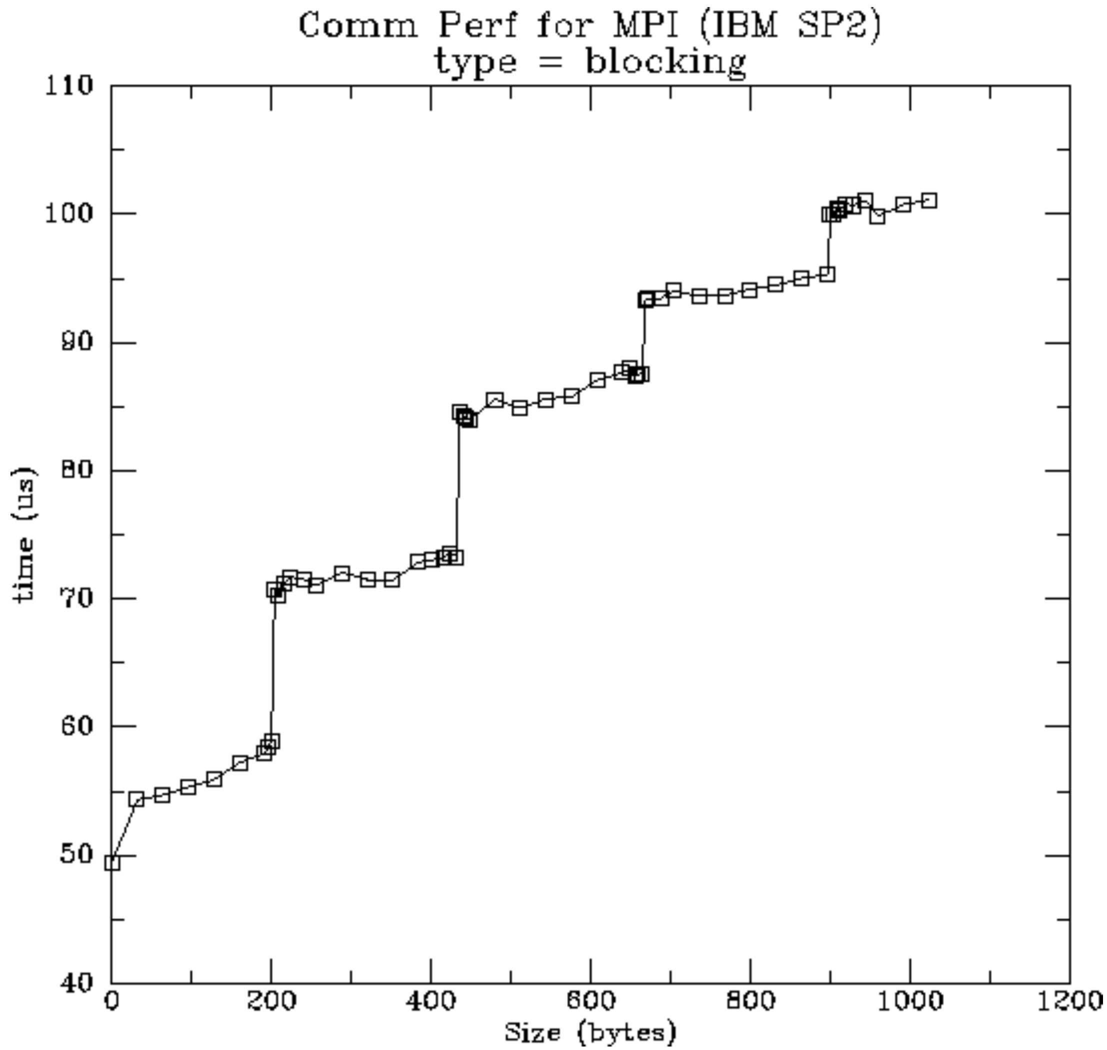
- Some networks send data in discrete chunks called *packets*



Introduces a ceil(n/packet_size) term

Staircase appearance of performance graph

Example of Packetization



Packets contain 232 bytes of data. (first is 200 bytes, so MPI header is probably 32 bytes).

Data from mpptest, available at ftp://ftp.mcs.anl.gov/pub/mpi/misc/perftest.tar.gz