Dealing with the Scale Problem

Presented by

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Binomial graph

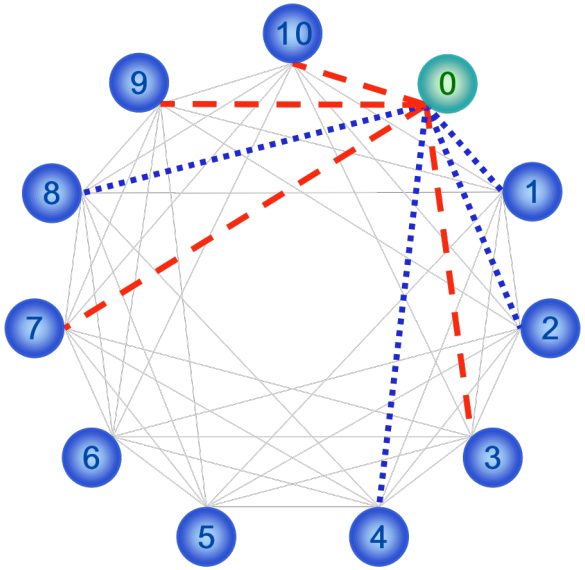
Undirected graph $G:=(V, E)$, $|V|=n$ (any size)

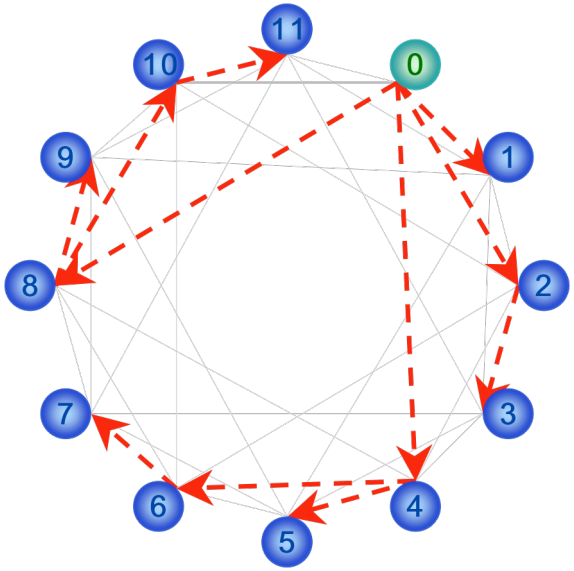
Node $i=\{0,1,2,\ldots,n-1\}$ has links to a set of nodes U

$U=\{i\pm1, i\pm2,\ldots, i\pm2^k \mid 2^k \le n\}$ in a circular space

$U=\{ (i+1)\bmod n, (i+2)\bmod n,\ldots, (i+2^k)\bmod n \mid 2^k \le n \}$ and

$\{ (n+i-1)\bmod n, (n+i-2)\bmod n,\ldots, (n+i-2^k)\bmod n \mid 2^k \le n \}$





Merging all links create binomial graph from each node of the graph

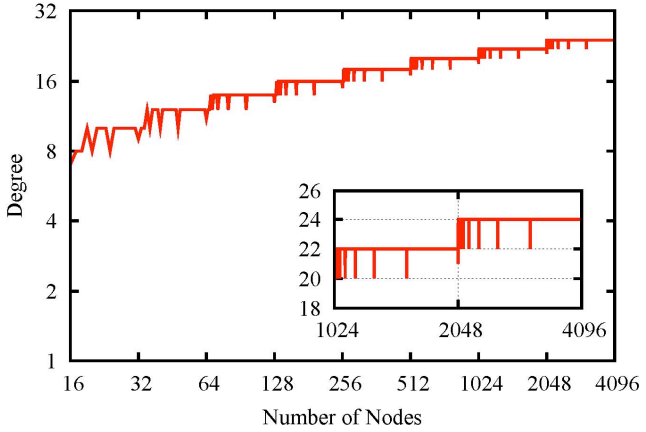
Broadcast from any node in $Log_2(n)$ steps

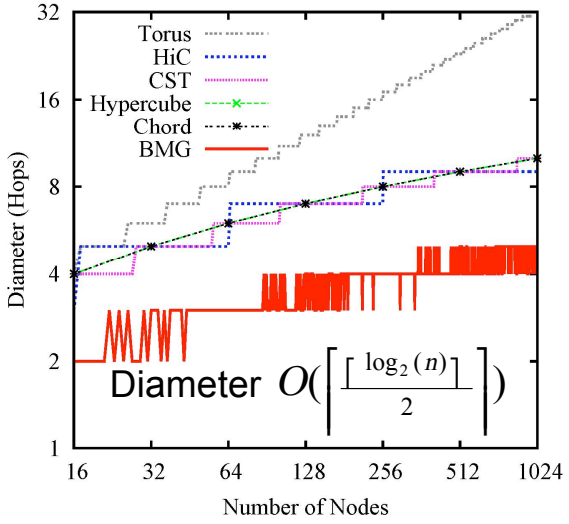
Runtime scalability

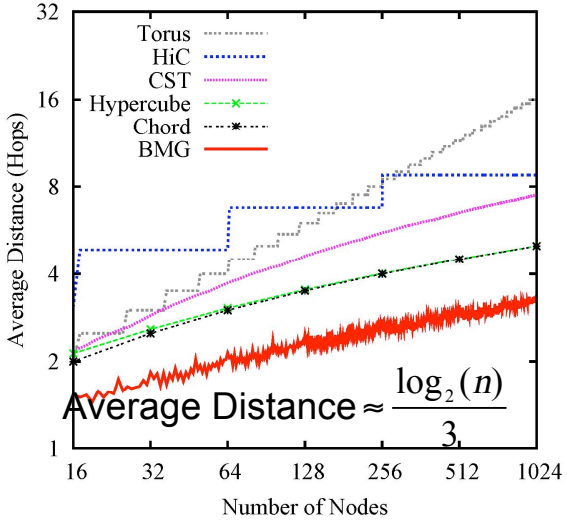
Binomial graph properties

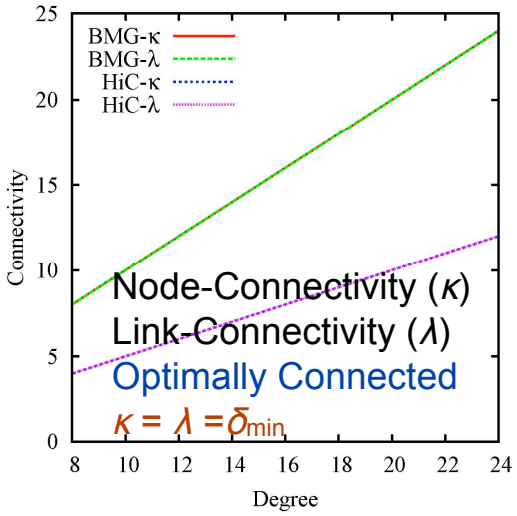
Degree = number of neighbors
= number of connections
= resource consumption

$$\delta = \begin{cases} (2 \times \lceil \log_2 n \rceil) - 1 & \text{For } n = 2^k, \text{where } k \in \mathbb{N} \\ (2 \times \lceil \log_2 n \rceil) - 2 & \text{For } n = 2^k + 2^j, \text{where } k, j \subset \mathbb{N} \wedge k \neq \\ 2 \times \lceil \log_2 n \rceil & \text{Otherwise} \end{cases}$$







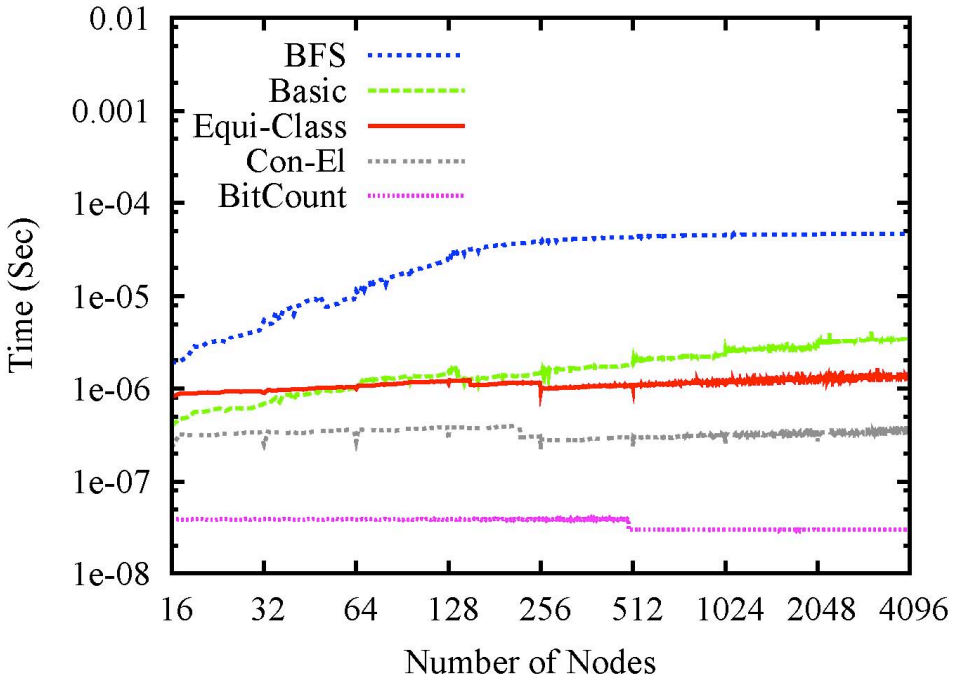


Runtime scalability

Routing cost

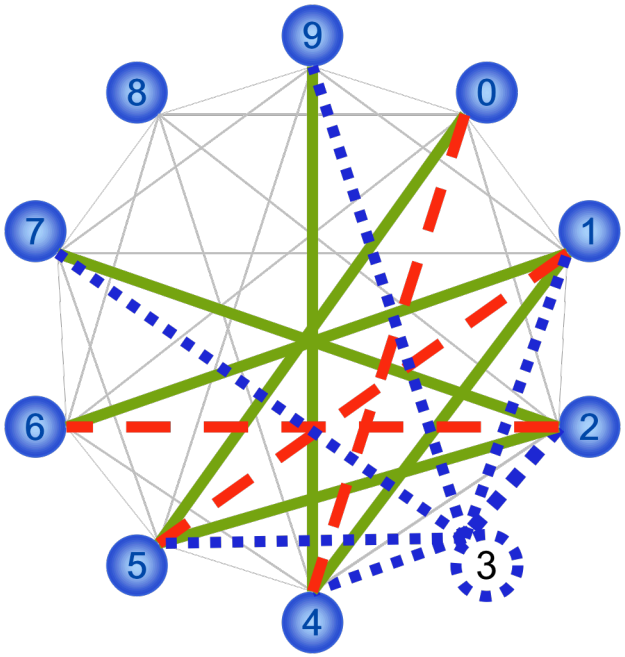
- Because of the counter-clockwise links the routing problem is NP-complete.
- Good approximations exist, with a max overhead of 1 hop.

- Broadcast: optimal in number of steps $\log_2(n)$ (binomial tree from each node)
- Allgather: Bruck algorithm $\log_2(n)$ steps
  - At step s:
    - Node i send data to node i-2s
    - Node i receive data from node i+2s

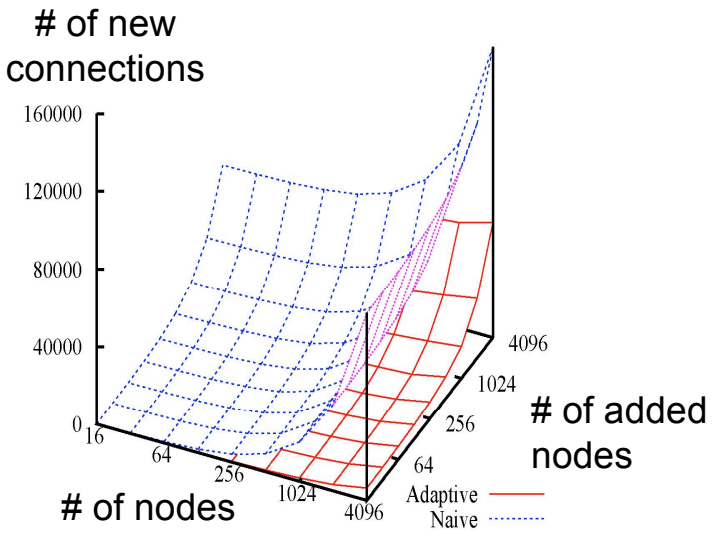


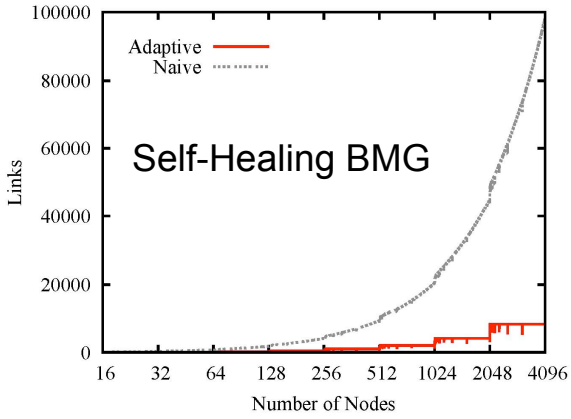
Runtime scalability

Dynamic environments



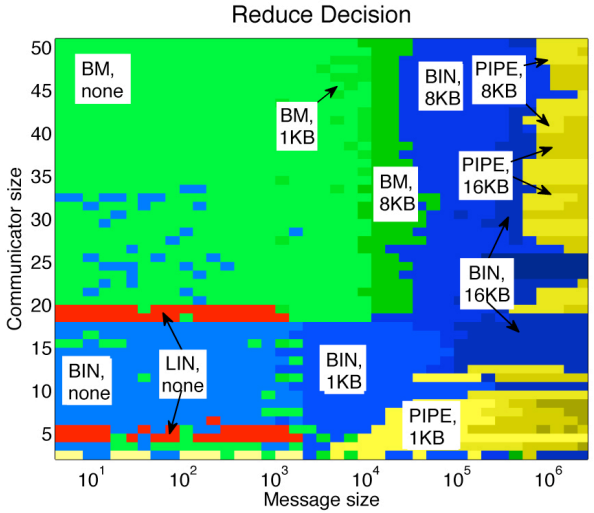
Runtime scalability





Optimization process

- Run-time selection process
  - We use performance models, graphical encoding, and statistical learning techniques to build platform-specific, efficient, and fast runtime decision functions.



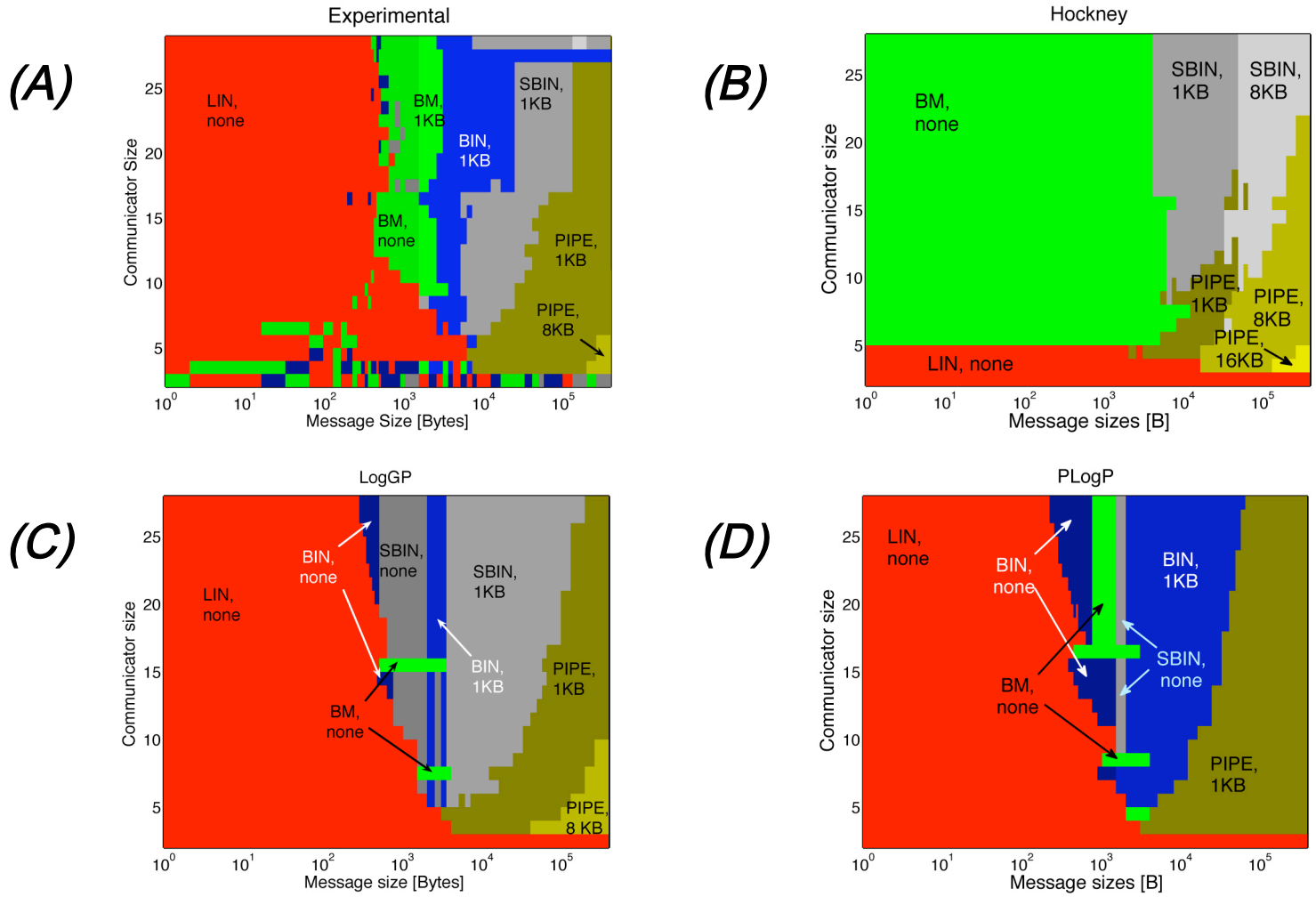
Comm size	Msg size	Algorithm	Seg size	Method index
3	1	Linear	none	15
3	2	Linear	none	15
...	...	...	...	...
50	1MB	Pipeline	8KB	24
...	...	...	...	...

Decision Tree:

```
message_size <= 512 :
|  communicator_size <= 4 :
| |  message_size <= 32 : ring (12.0/1.3)
| |  message_size > 32 : linear (8.0/2.4)
| communicator_size > 4 :
| |  communicator_size > 8 : bruck (100.0/1.4)
| |  communicator_size <= 8 :
| | |  message_size <= 128 : bruck (8.0/1.3)
| | |  message_size > 128 : linear (2.0/1.0)
message_size > 512 :
|  message_size > 1024 : linear (78.0/1.4)
|  message_size <= 1024 :
| |  communicator_size > 56 : linear (5.0/1.2)
| |  communicator_size <= 56 :
| | |  communicator_size <= 8 : linear (3.0/1.1)
| | |  communicator_size > 8 : bruck (5.0/1.2)
```

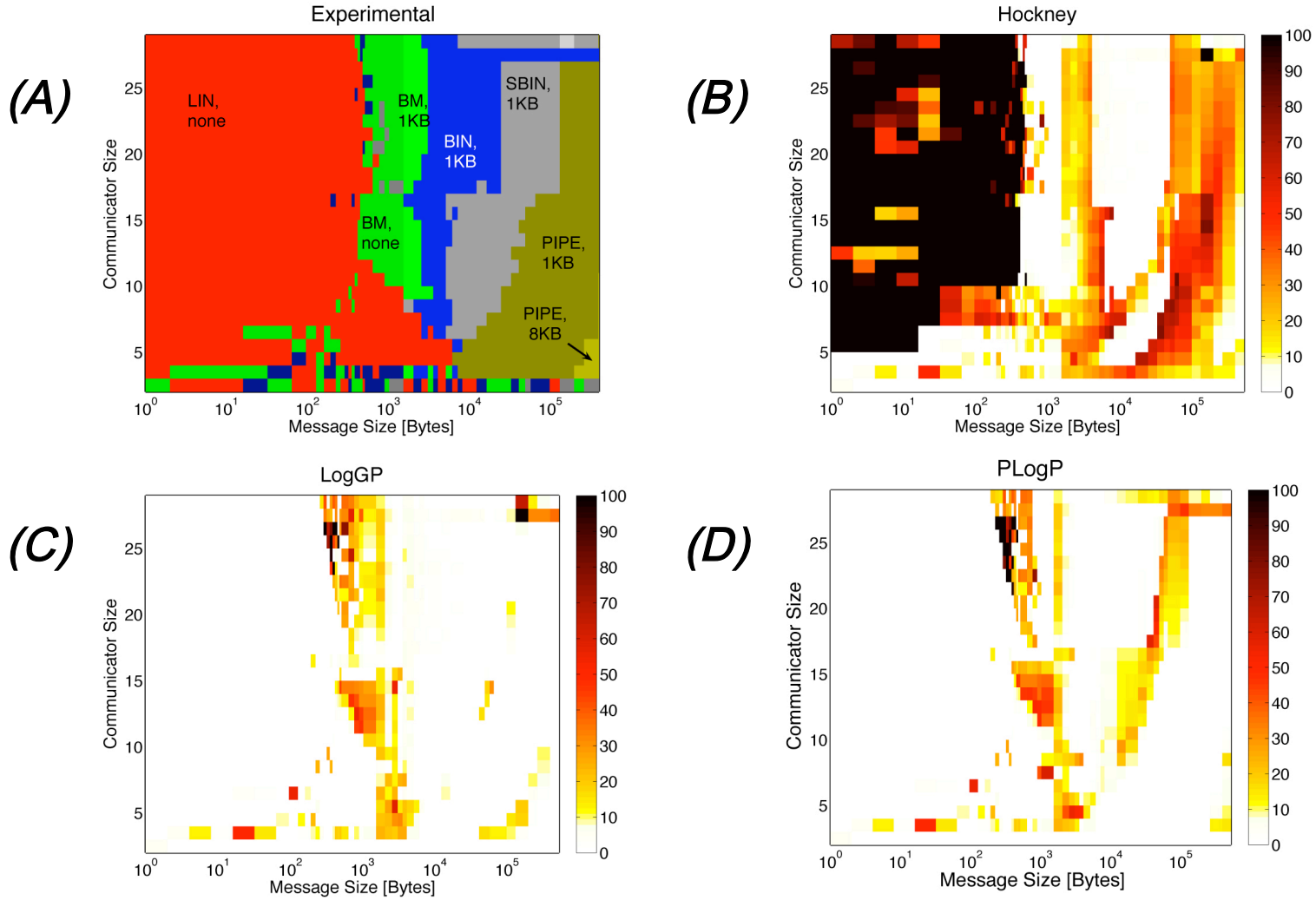
Collective communications

Model prediction



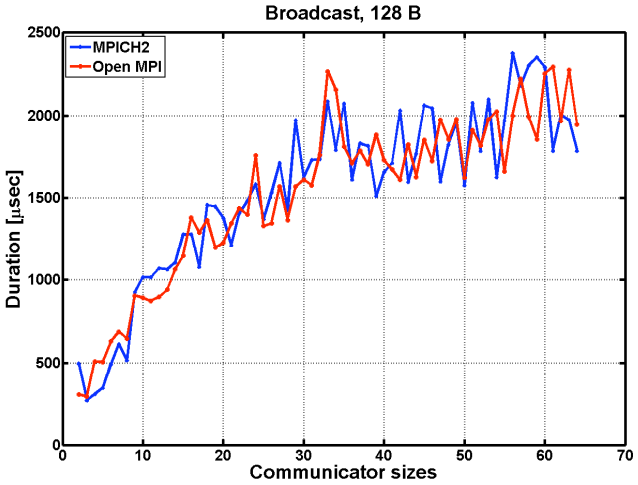
Collective communications

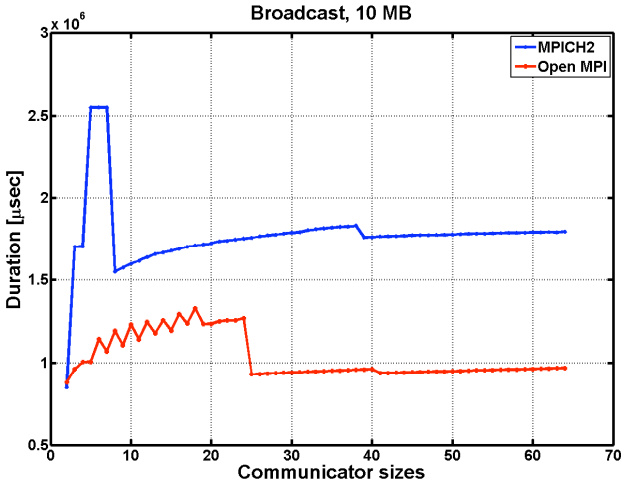
Model prediction



Collective communications

Tuning broadcast

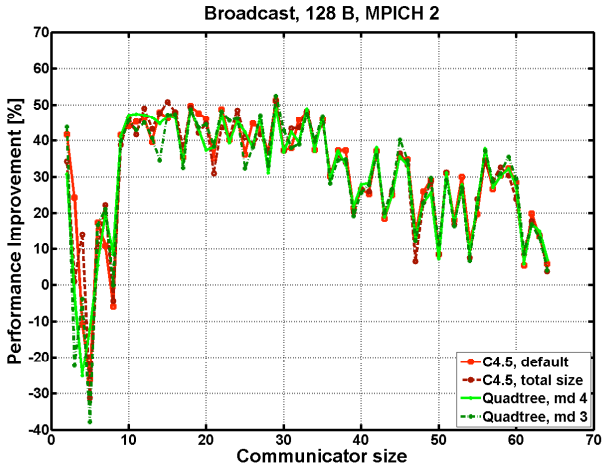


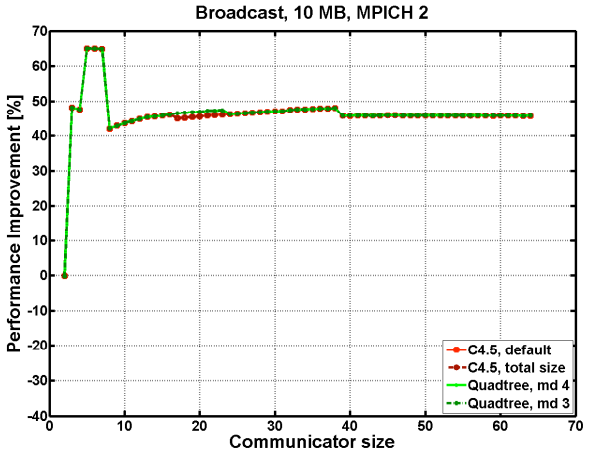


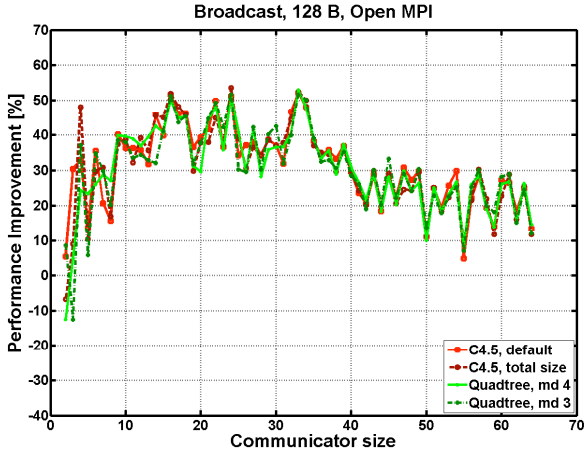
64 Opterons with1Gb/s TCP

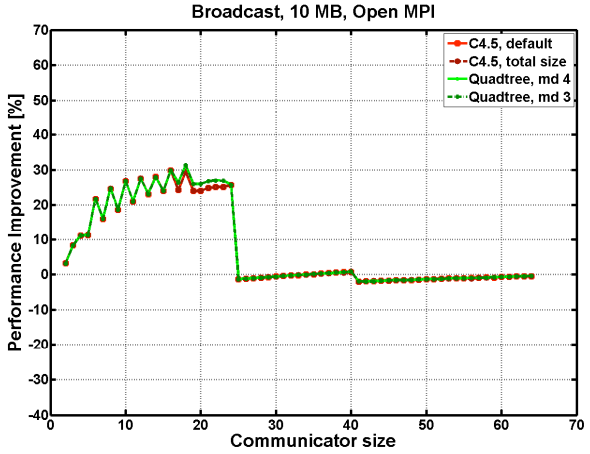
Collective communications

Tuning broadcast









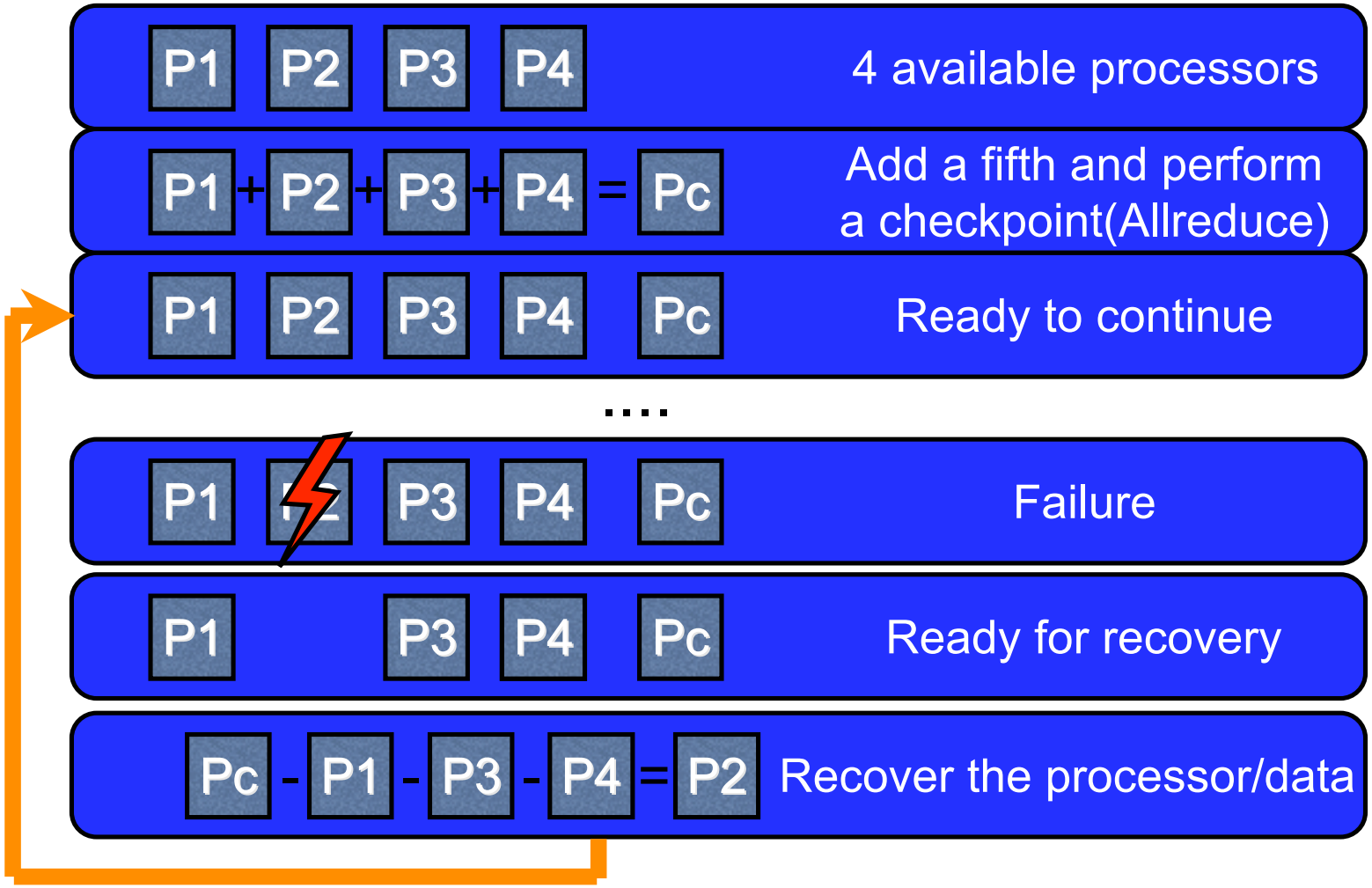
Collective communications

Application tuning

- Parallel Ocean Program (POP) on a Cray XT4.
  - Dominated by MPI_Allreduce of 3 doubles.
- Default Open MPI select recursive doubling
  - Similar with Cray MPI (based on MPICH).
  - Cray MPI has better latency.
  - I.e., POP using Open MPI is 10% slower on 256 processes.
- Profile the system for this specific collective and determine that “reduce + bcast” is faster.
  - Replace the decision function.
  - New POP performance is about 5% faster than Cray MPI.

Collective communications

Diskless checkpointing



Fault tolerance

Diskless checkpointing

- How to checkpoint?
  - Either floating-point arithmetic or binary arithmetic will work.
  - If checkpoints are performed in floating-point arithmetic then we can exploit the linearity of the mathematical relations on the object to maintain the checksums.
- How to support multiple failures?
  - Reed-Salomon algorithm.
  - Support p failures require p additional processors (resources).

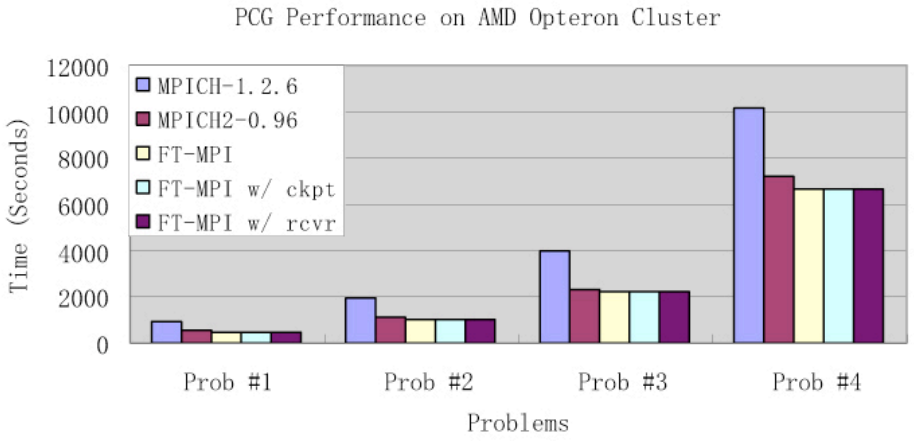
Fault tolerance

PCG

- Fault tolerant CG
- 64x2 AMD 64 connected using GigE

	Size of the Problem	Num. of Comp. Procs
Prob #1	164,610	15
Prob #2	329,220	30
Prob #3	658,440	60
Prob #4	1,316,880	120

Performance of PCG with different MPI libraries



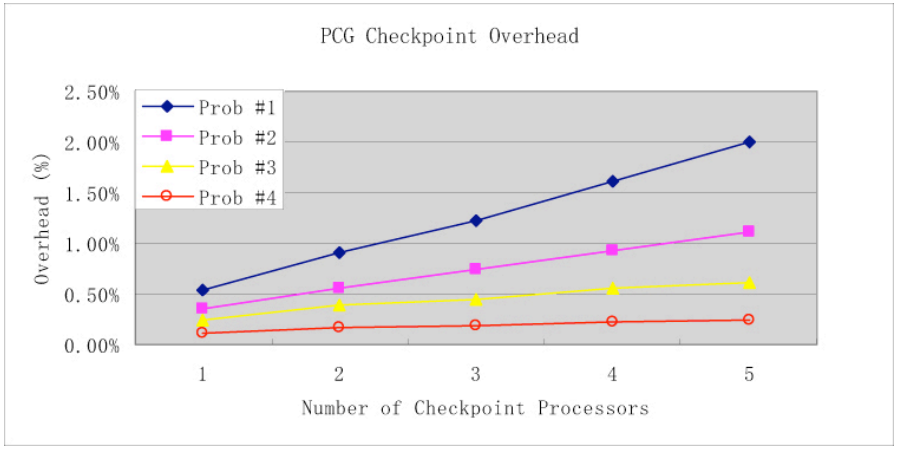
For ckpt we generate one ckpt every 2000 iterations

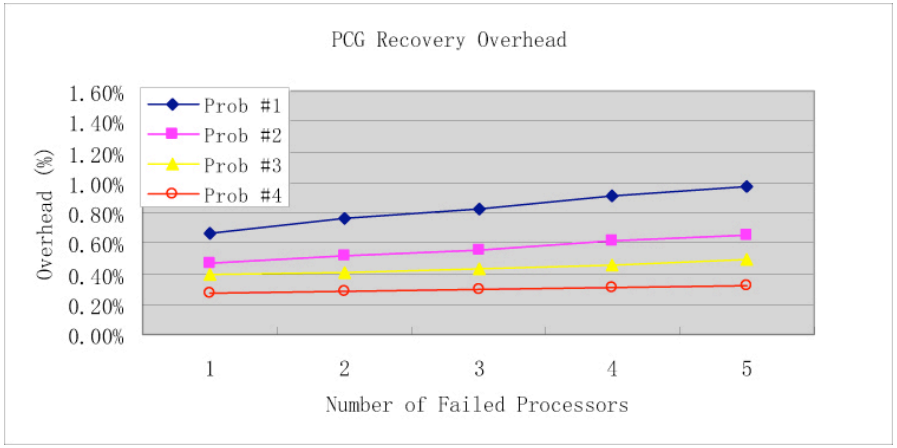
Fault tolerance

PCG

Time	Prob #1	Prob #2	Prob #3	Prob #4
1 ckpt	2.6	3.8	5.5	7.8
2 ckpt	4.4	5.8	8.5	10.6
3 ckpt	6.0	7.9	10.2	12.8
4 ckpt	7.9	9.9	12.6	15.0
5 ckpt	9.8	11.9	14.1	16.8

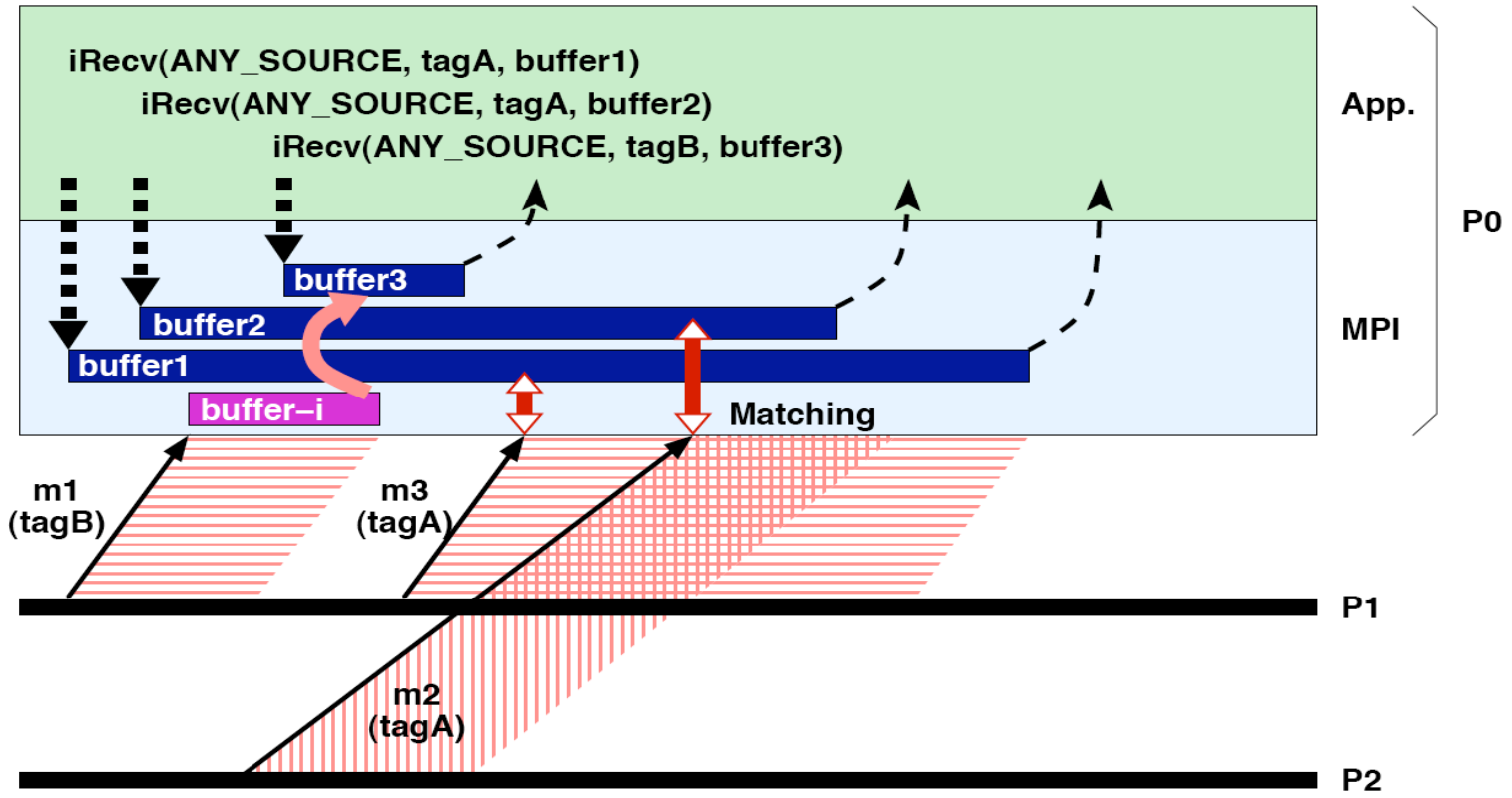
Checkpoint overhead in seconds





Fault tolerance

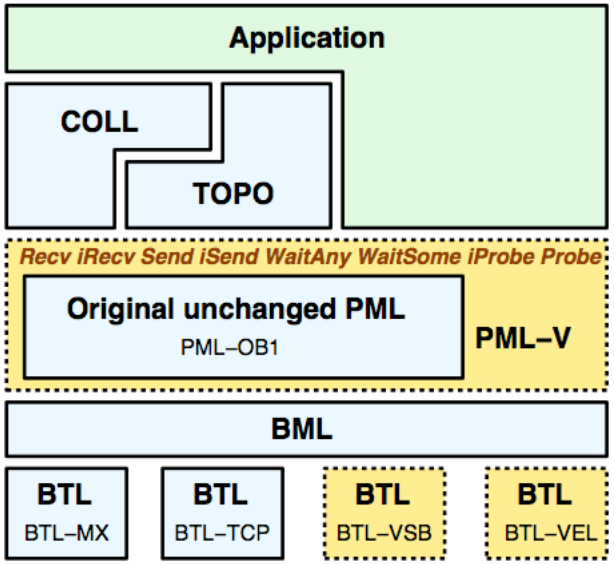
Detailing event types to avoid intrusiveness



Fault tolerance

Interposition in Open MPI

- We want to avoid tainting the base code with #ifdef FT_BLALA.
- Vampire PML loads a new class of MCA components.
  - Vprotocols provide the entire FT protocol (only pessimistic for now).
  - You can use the ability to define subframeworks in your components!
- Keep using the optimized low level and zero-copy devices (BTL) for communication.
- Unchanged message scheduling logic.



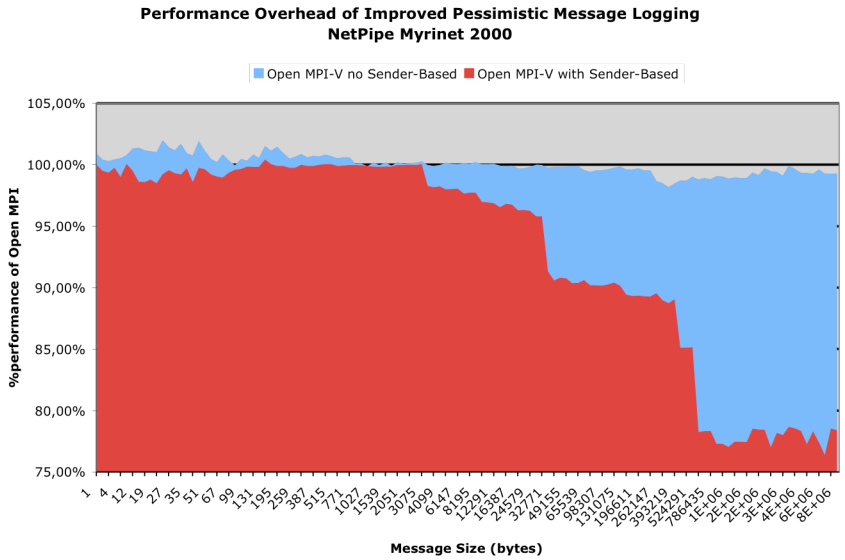
Fault tolerance

Performance overhead

	BT	SP	FT	CG	MG						LU					
#processors	all				4	32	64	256	512	1024	4	32	64	256	512	1024
%non-deterministic	0	0	0	0	40.33	29.35	27.10	22.23	20.67	19.99	1.13	0.66	0.80	0.80	0.75	0.57

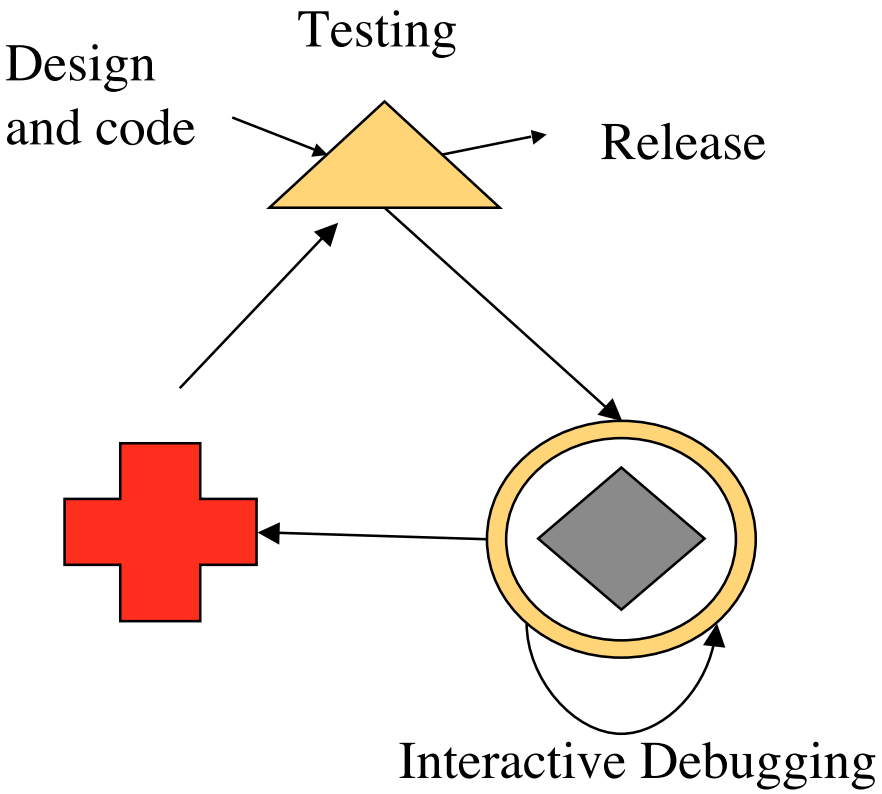
Table 1. Percentage of non-deterministic events to total number of exchanged messages on the NAS Parallel Benchmarks (Giga-Ethernet, class B).

- Myrinet 2G (mx 1.1.5)—Opteron 146x2—2GB RAM—Linux 2.6.18—gcc/gfortran 4.1.2—NPB3.2—NetPIPE.
- Only two application kernels show non-deterministic events (MG, LU).



Fault tolerance

Debugging applications

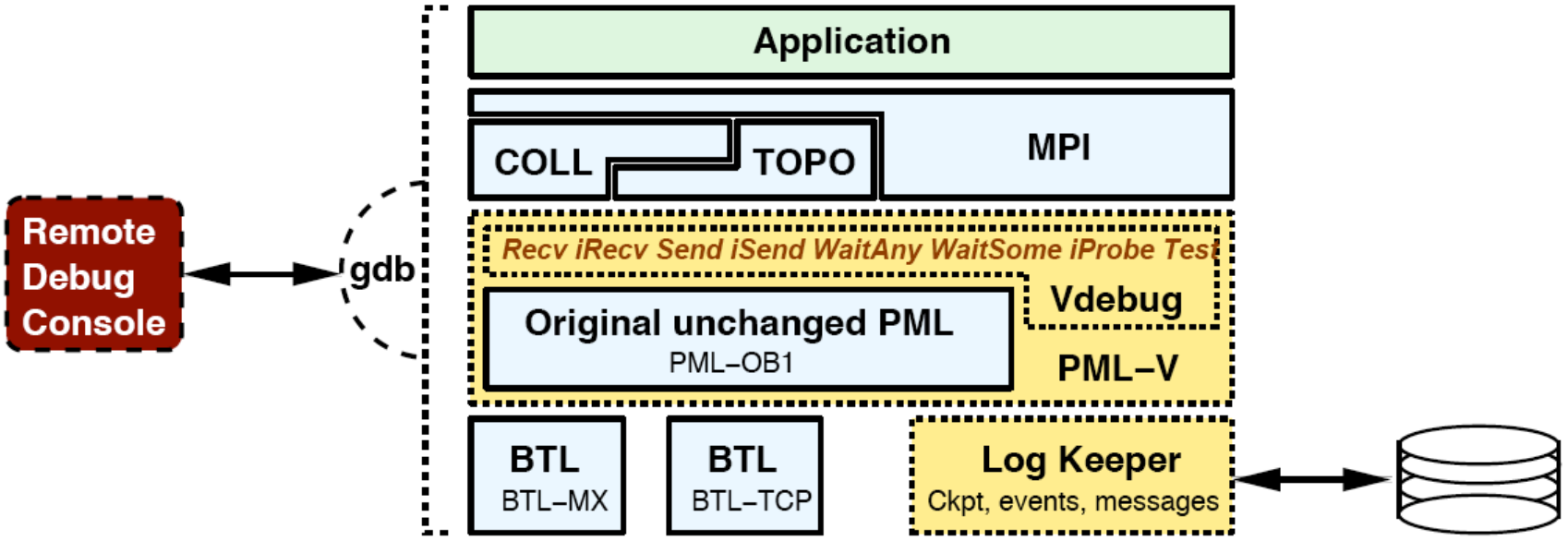


- Usual scenario involves
  - Programmer design testing suite
  - Testing suite shows a bug
  - Programmer runs the application in a debugger (such as gdb) up to understand the bug and fix it
  - Programmer runs the testing suite again
    - Cyclic debugging

Fault tolerance

Interposition Open MPI

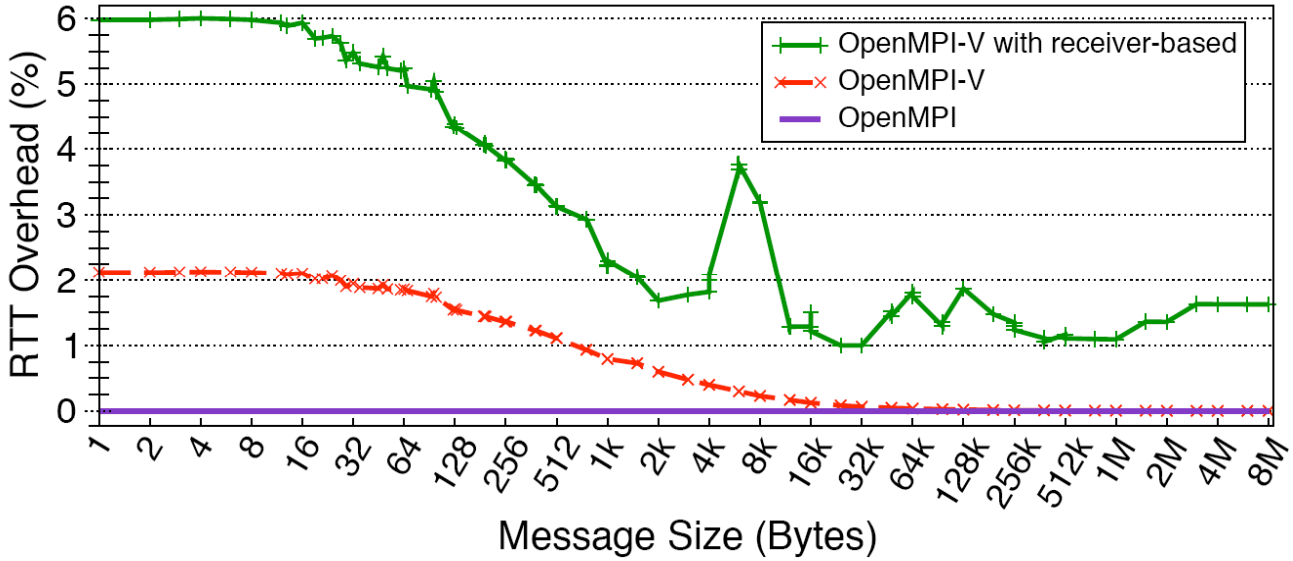
- Events are stored (asynchronously on disk) during initial run.
- Keep using the optimized low level and zero-copy devices (BTL) for communication.
- Unchanged message scheduling logic.
- We expect low impact on application behavior.



Fault tolerance

Performance overhead

- Myrinet 2G (mx 1.0.3)—Opteron 146x2—2GB RAM—Linux 2.6.18—gcc/gfortran 4.1.2—NPB3.2—NetPIPE
- 2% overhead on bare latency, no overhead on bandwidth.
- Only two application kernels show non-deterministic events.
- Receiver-based has more overhead; moreover, it incurs large amount of logged data—350 MB on simple ping-pong (this is beneficial; it is enabled on-demand).



Vdebug Application overhead (%)		
Rcvr-based	None	Yes
BT.B.64	0	6.4
LU.B.64	0	2.2
MG.B.64	2.2	4
CG.B.64	0.8	4
FT.B.64	0	7.3
SP.B.64	0	6.4
EP.B.64	0	0

Fault tolerance

Log size on NAS parallel benchmarks

Log size per process on NAS Parallel Benchmarks (kB)

#procs	4	8	16	32	64	128	256	512	1024	Average
LU.B	11.2	11.2	11.9	10.6	13.9	19	14.9	14.2	12.7	13.3
MG.B	11.2	11.2	10.8	10.6	10.6	9.8	9.5	9.3	9.2	10.24

- Among the 7 NAS kernels, only 2 NPB generates nondeterministic events.
- Log size does not correlate with number of processes.
- The more scalable is the application, the more scalable is the log mechanism.
- Only 287KB of log/process for LU.C.1024 (200MB memory footprint/process).

Fault tolerance

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