Surviving in the Petascale World [and Beyond]

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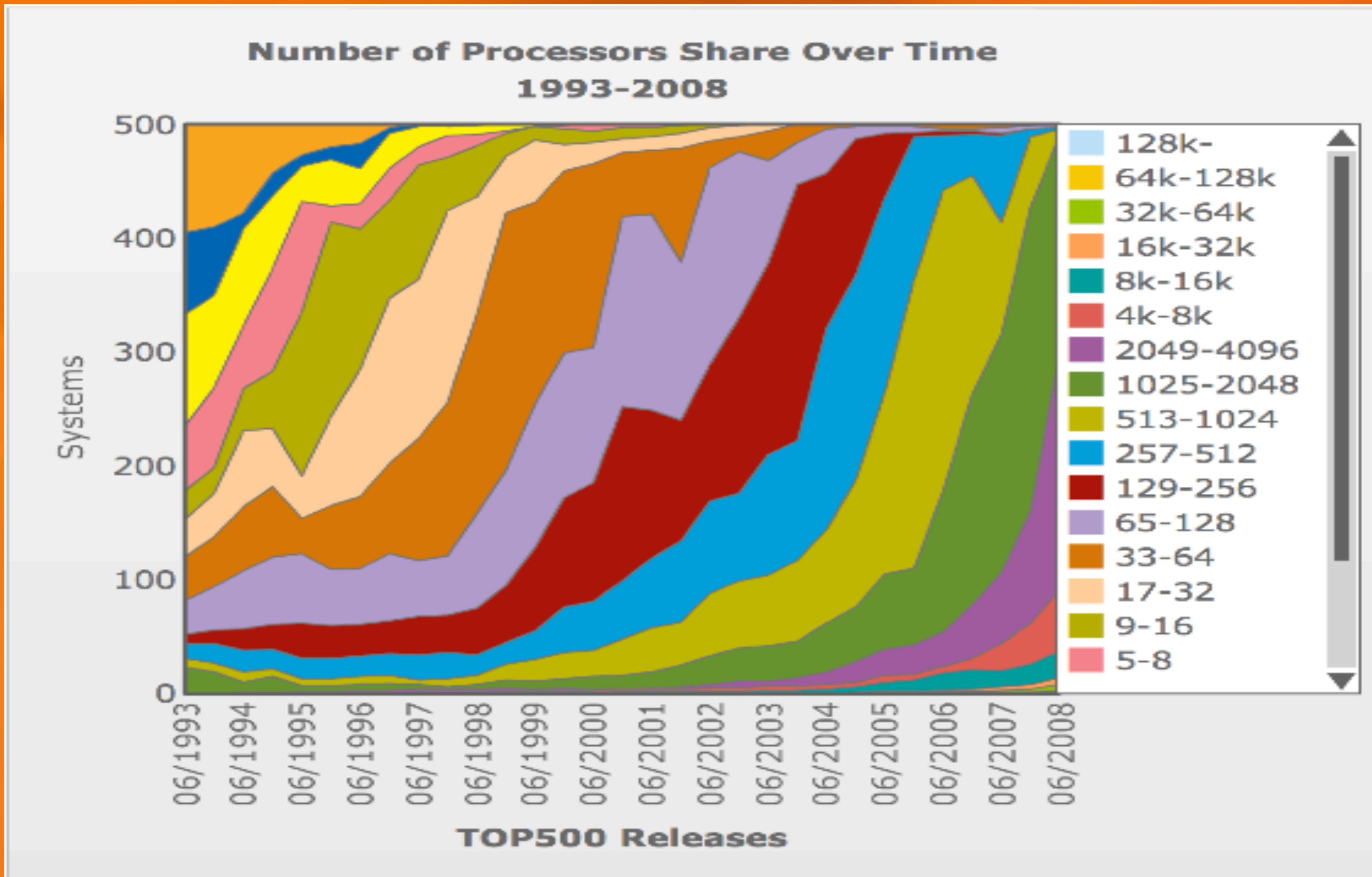
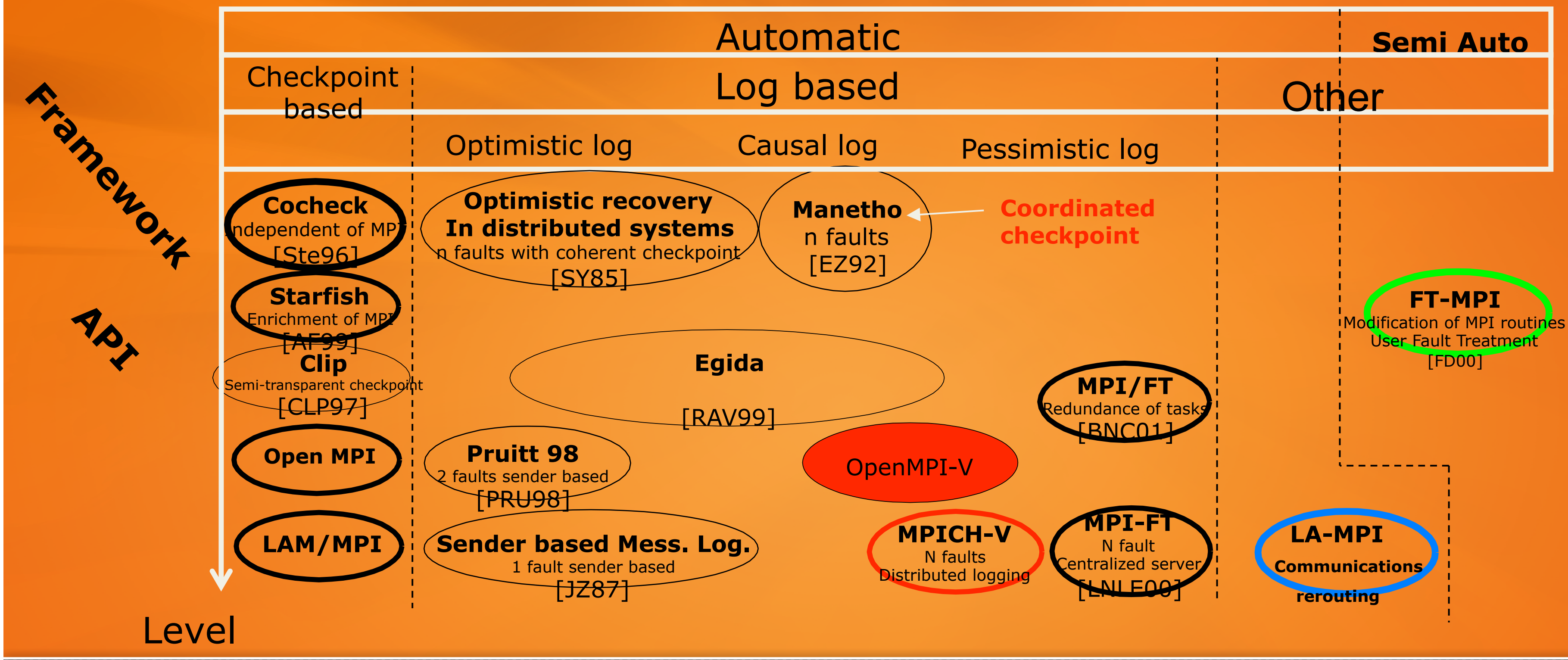

Number of Processors Share Over Time
1993-2008
Systems
500
400
300
200
100
0
06/1993
06/1994
06/1995
06/1996
06/1997
06/1998
06/1999
06/2000
06/2001
06/2002
06/2003
06/2004
06/2005
06/2006
06/2007
06/2008
TOP500 Releases
128k-
64k-128k
32k-64k
16k-32k
8k-16k
4k-8k
2049-4096
1025-2048
513-1024
257-512
129-256
65-128
33-64
17-32
9-16
5-8

Classification of FT approaches



FT a complex solution

Transparency

- application ckpt: application stores intermediate results and restart form them
- MP API+FM: message passing API returns errors to be handled by the programmer
- automatic: runtime detects faults and handle recovery

Checkpoint coordination

- coordinated: all processes are synchronized, network is flushed before ckpt; all processes rollback from the same snapshot
- uncoordinated: each process checkpoint independently of the others; each process is restarted independently of the others

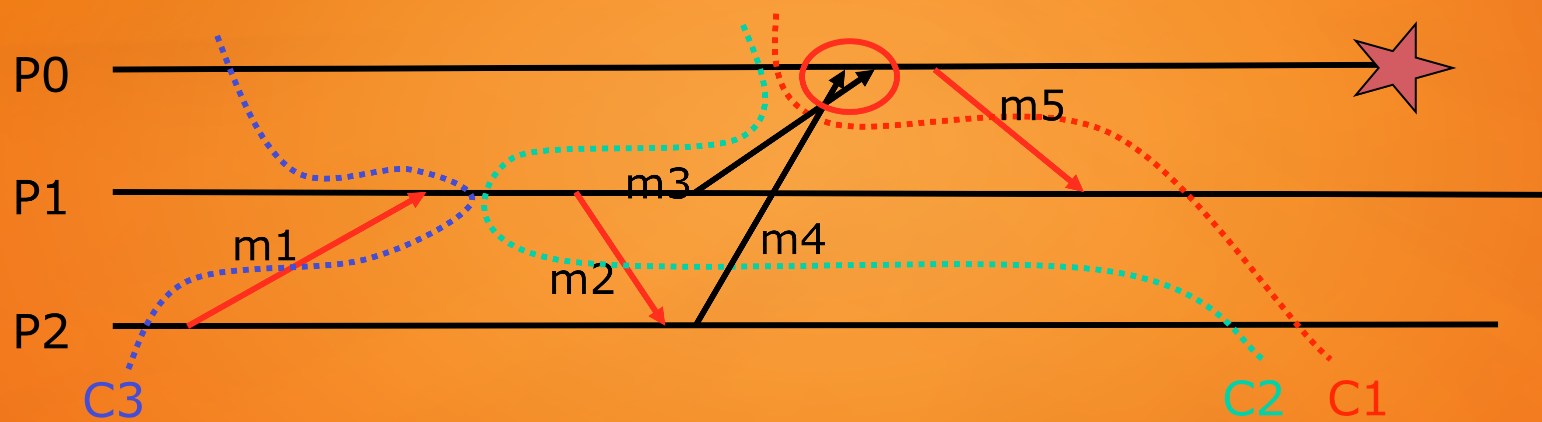
FT a complex solution

Message logging

- pessimistic: all messages are logged on reliable media and used for replay
- optimistic: all messages are logged on non reliable media. If 1 node fails, replay is done according to other nodes logs. If >1 node fail, rollback to last coherent checkpoint
- causal: optimistic + Antecedence Graph, reduces the recovery time

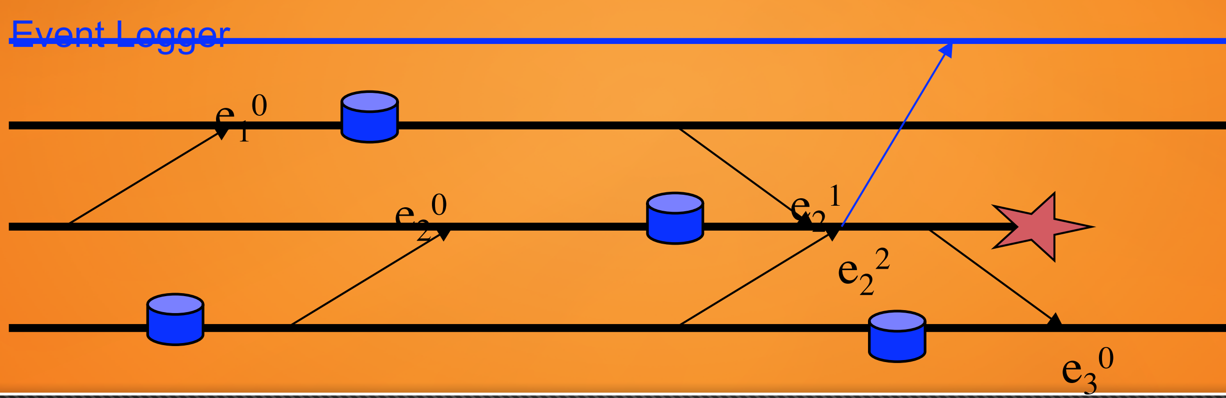
The problem of inconsistent states

- Order of message receptions are non-deterministic events
- messages received but not sent are inconsistent
- Domino effect can lead to rollback to the begining of the execution in case of even a single fault
- Possible loose of the whole execution and unpredictive fault cost



Deterministic Recovery

- Deterministic replay is based on ***Event Logging***
- ***Piecewise Deterministic*** assumption (even suitable for monte carlo applications)
- Each recv is an event (src,send-clk,recv-clk)
- Send the ordering of events to stable storage (event logger)

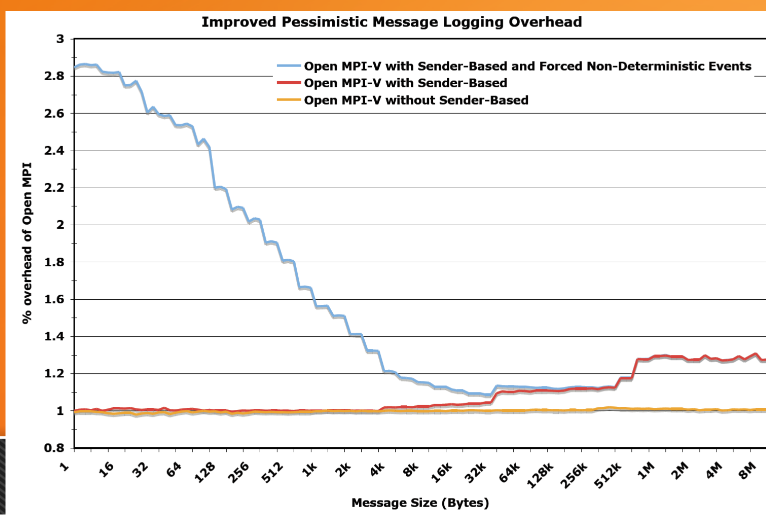


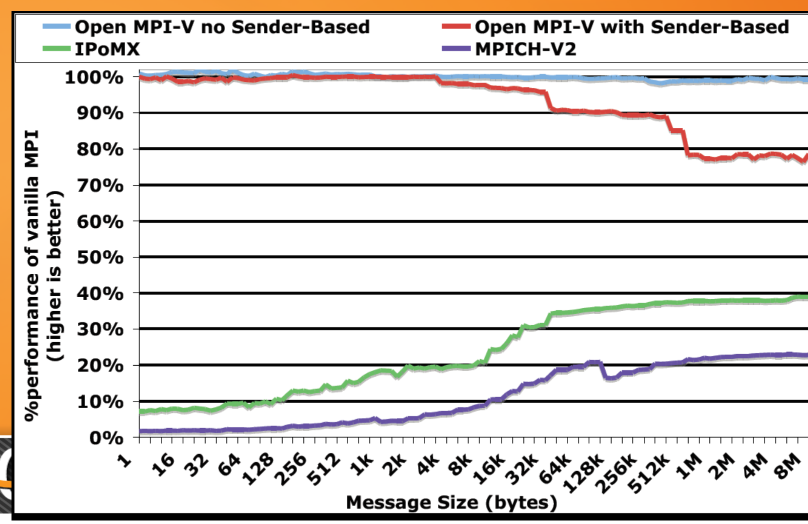
Benchmark Performance

- Number of logged events to total number of messages

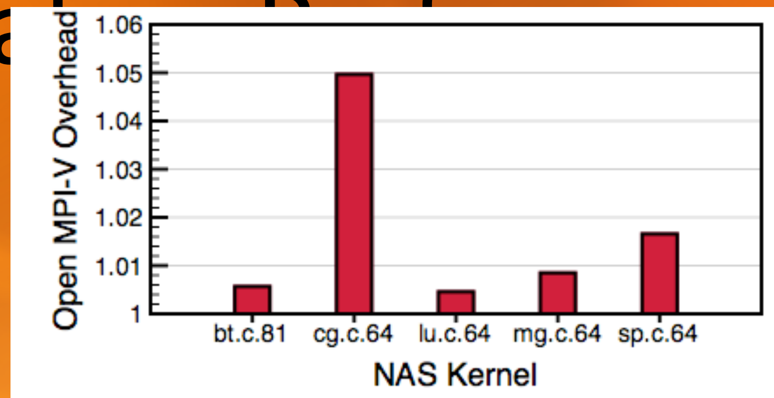
	BT	SP	FT	CG	MG						LU					
#processors	all				4	32	64	256	512	1024	4	32	64	256	512	1024
%non-deterministic	0	0	0	0	40.33	29.35	27.10	22.23	20.67	19.99	1.13	0.66	0.80	0.80	0.75	0.57

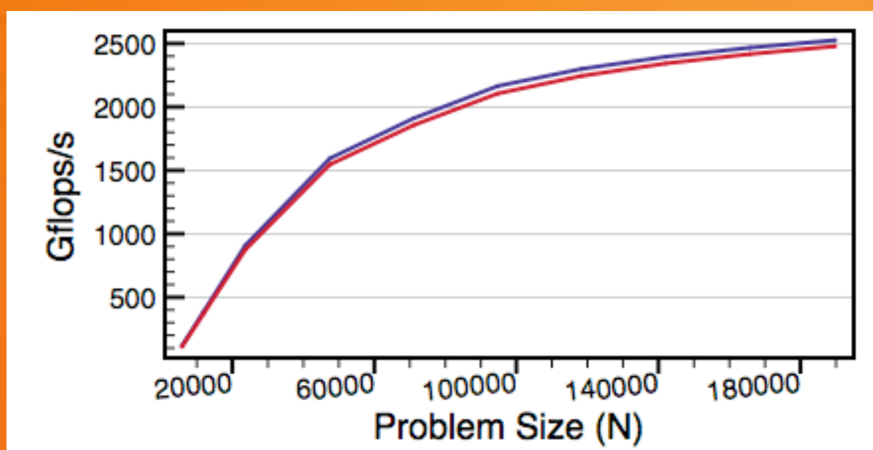
- Impact on latency of forced message logging (Infiniband)

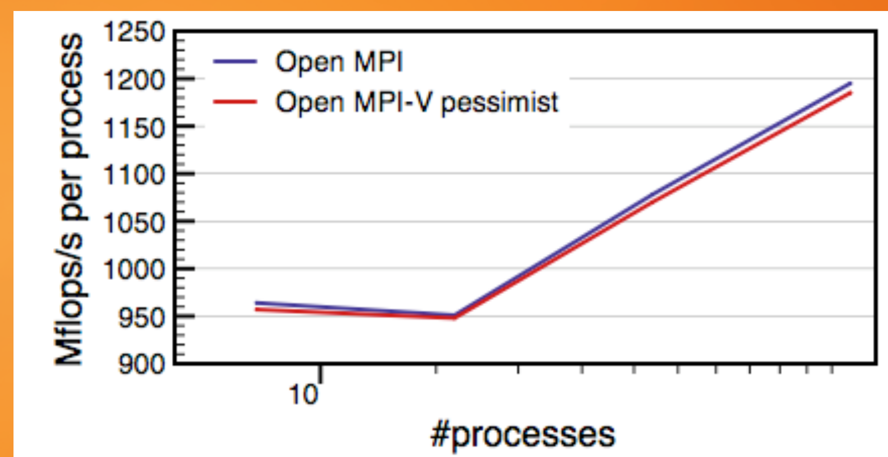




Applica ce and







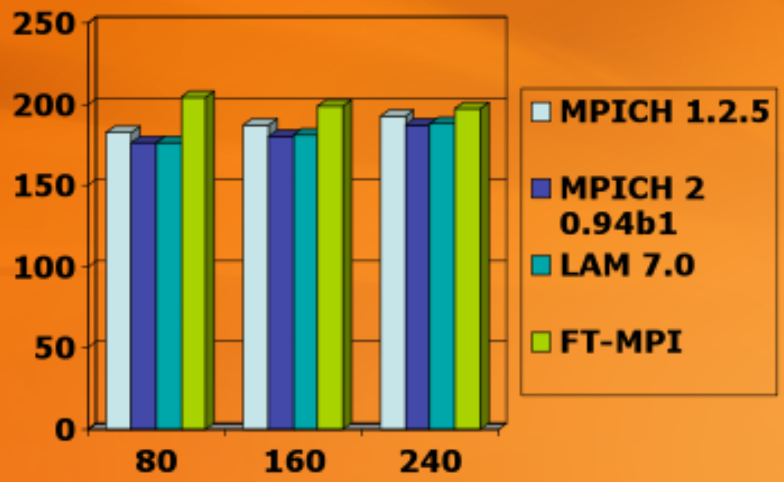
FT-MPI: Why and How ?

- MPI is the de-facto programming model for parallel applications
- MPI Standard: *"Advice to implementors: A good quality implementation will, to the greatest possible extent, circumvent the impact of an error, so that normal processing can continue after an error handler was invoked."*
- Define the behavior of MPI [state] in case an error occurs and give the application the possibility to recover from a node-failure
- A regular, non fault-tolerant MPI program will run using FT-MPI
- Follows the MPI-1 and MPI-2 specification as closely as possible (e.g. no additional function calls)
- On error user program must do something (!)

Recovery modes

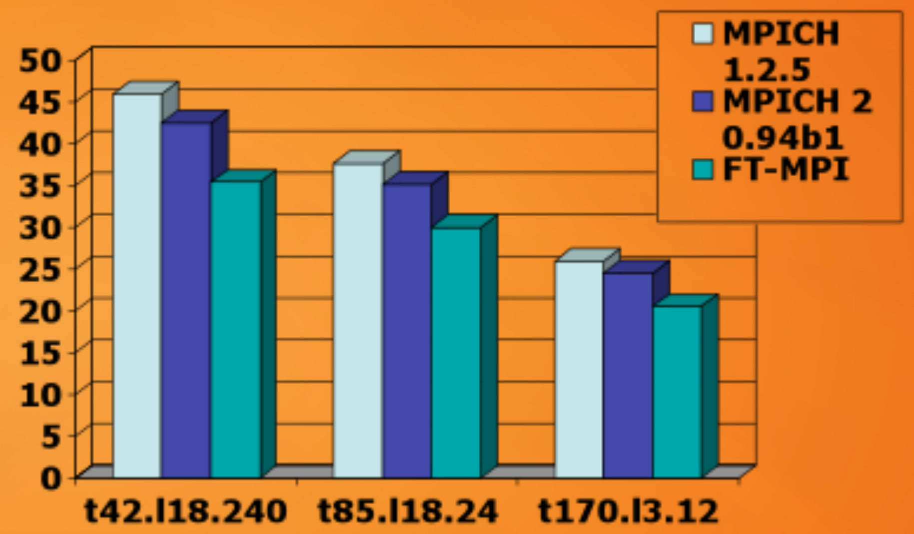
- ABORT, BLANK, SHRINK and REBUILD
- REBUILD: a new process is created, and it will return MPI_INIT_RESTARTED_PROC from MPI_Init
- BLANK: dead processes replaced by MPI_PROC_NULL, all communications with such a process succeed, they do not participate in the collectives
  - two sub-modes: local and global

Shallow Water (PSTSWM) & HPL



HPL

PSTSWM



Diskless checkpointing

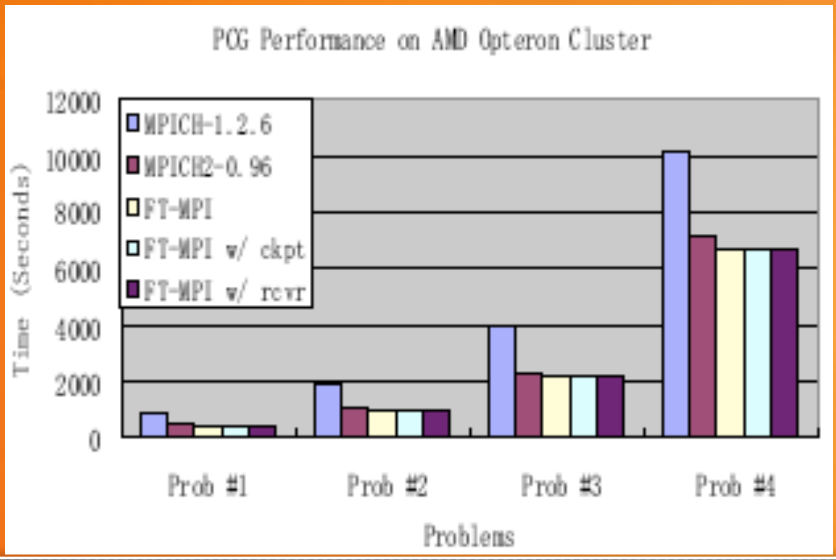
Diskless Checkpointing

- 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)

PCG

Fault Tolerant CG

	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

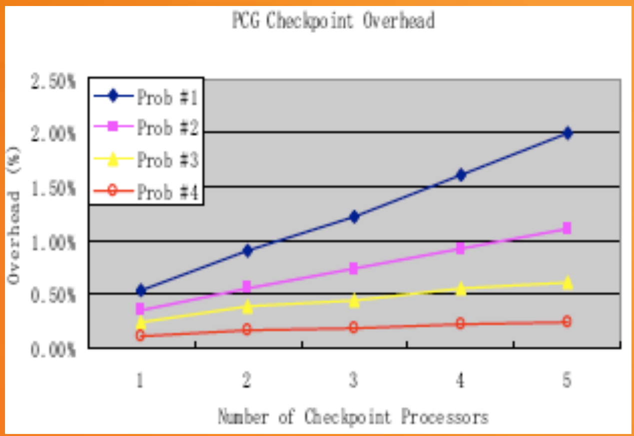


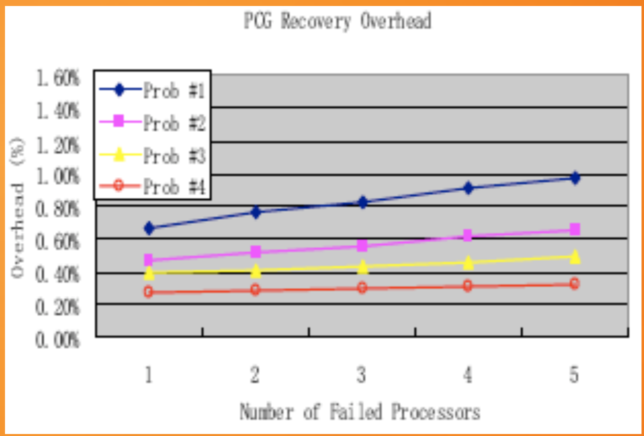
- Performance of PCG with different MPI libraries

PCG

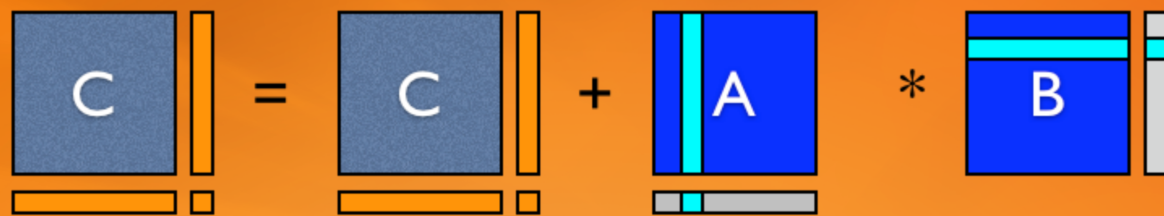
Time	Prob #1	Prob #2	Prob #3	Prob #4
1 ckpt	2.6	3.8	5.5	7.8
2 ckpt	4.4	5.8	8.5	10.6
3 ckpt	6.0	7.9	10.2	12.8
4 ckpt	7.9	9.9	12.6	15.0
5 ckpt	9.8	11.9	14.1	16.8

Checkpoint overhead in seconds





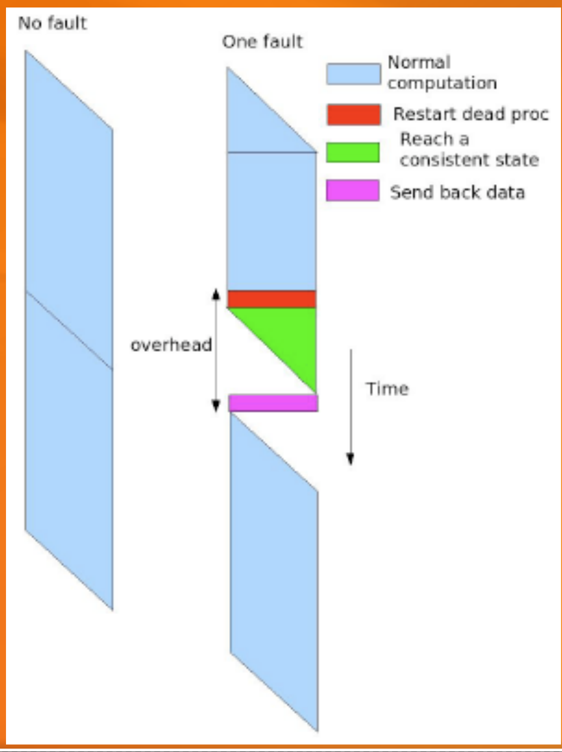
ABFT-PDGEMM



PDGEMM-SUMMA	ABFT-PDGEMM-SUMMA
$\frac{2n^3}{p}\gamma + 2(n + 2\sqrt{p} - 3)(\frac{n}{\sqrt{p}}\beta)$	$\frac{2n(n+nloc)^2}{p}\gamma + 2(n + 2\sqrt{p} - 3)(\frac{(n+nloc)}{\sqrt{p}}\beta)$

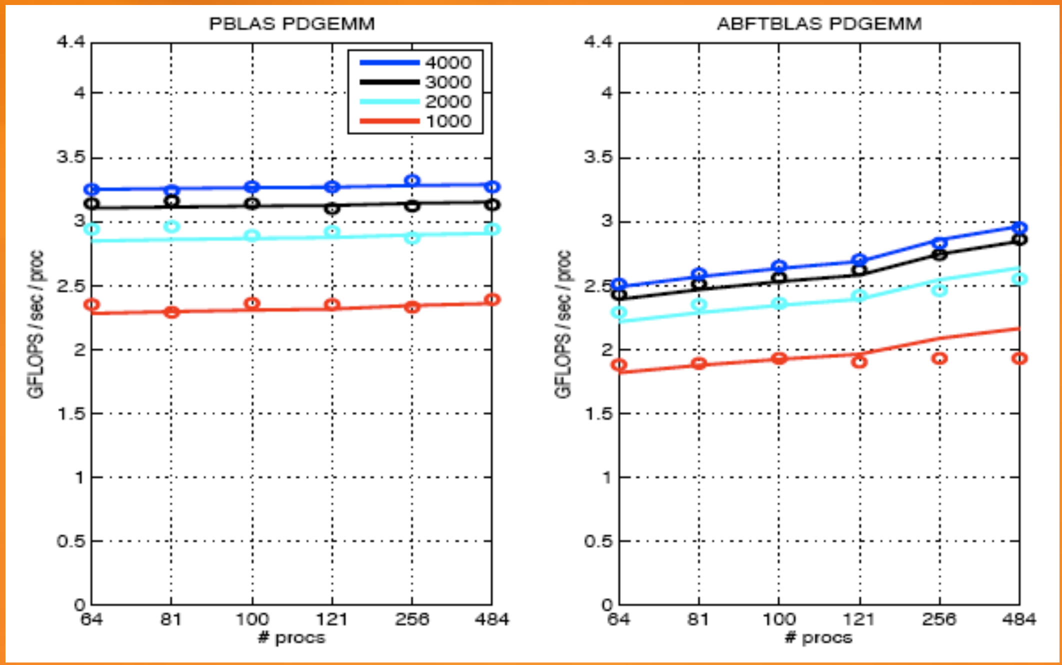
- The algorithm maintain the consistency of the checkpoints of the matrix C naturally

Failure Overhead

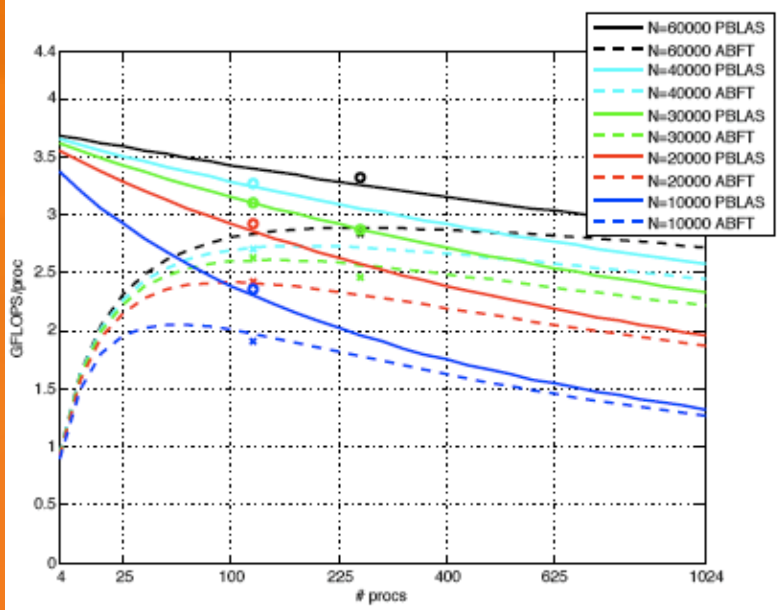


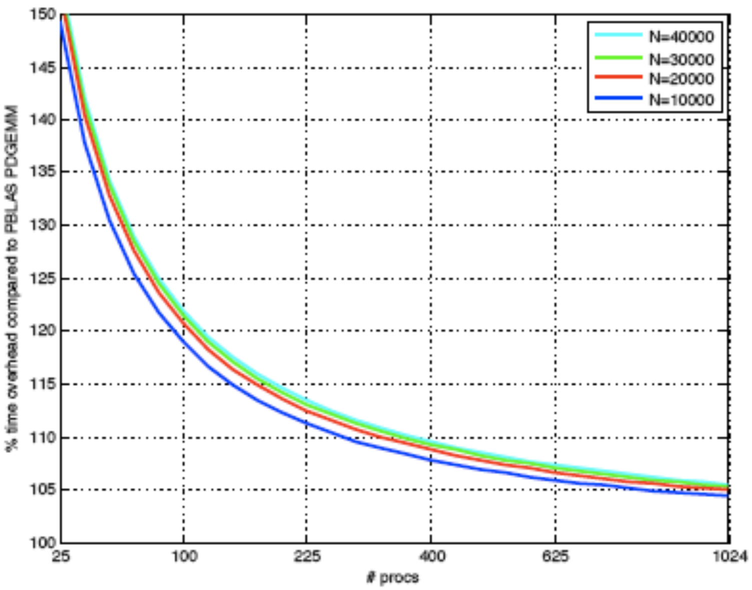
- FT-MPI will take care of the fault management
- Once the new process joins the MPI_COMM_WORLD we have to rebuild the communicators
- Then we have to retrieve the data from the checkpoint processor

PBLAS vs. ABFT BLAS (no failure)



Strong Scalability





Conclusion

- Fault Tolerance is a requirement
- Which model is the best depend on many factors
  - FT-MPI is a viable approach with algorithms already available.