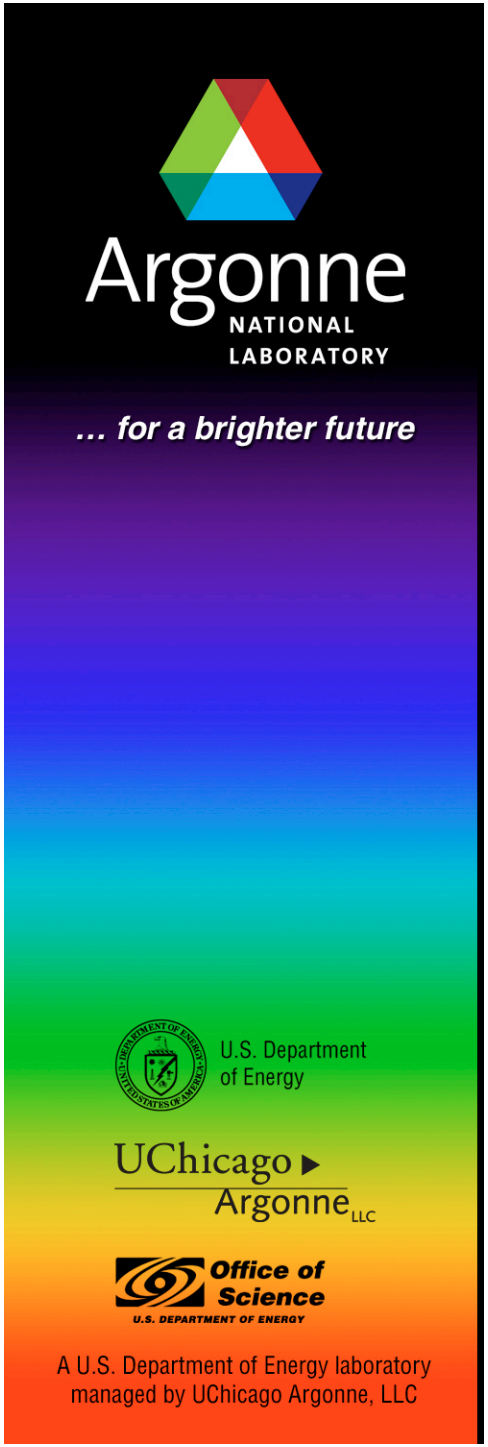

The Asynchronous Dynamic Load-Balancing Library

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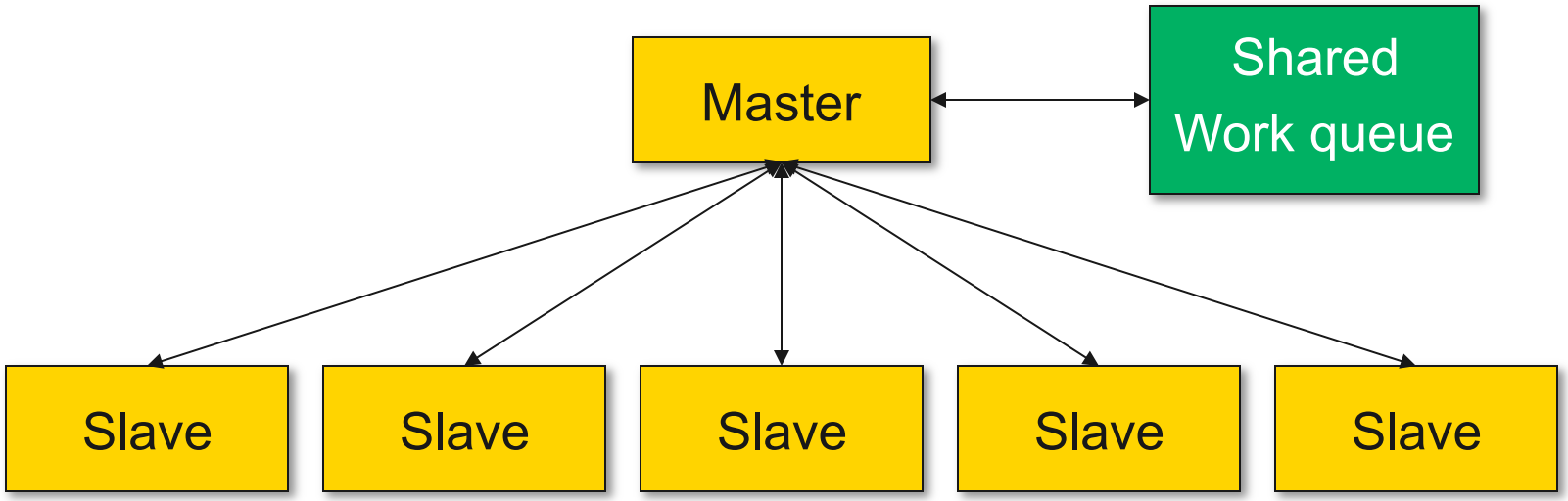
Outline

- Reminders about ADLB
  - What it is (PF 2007)
  - How to use it (PF 2008)
- This year: how it works
- Recent progress
- Challenges remaining

Master/Slave Algorithms and Load Balancing

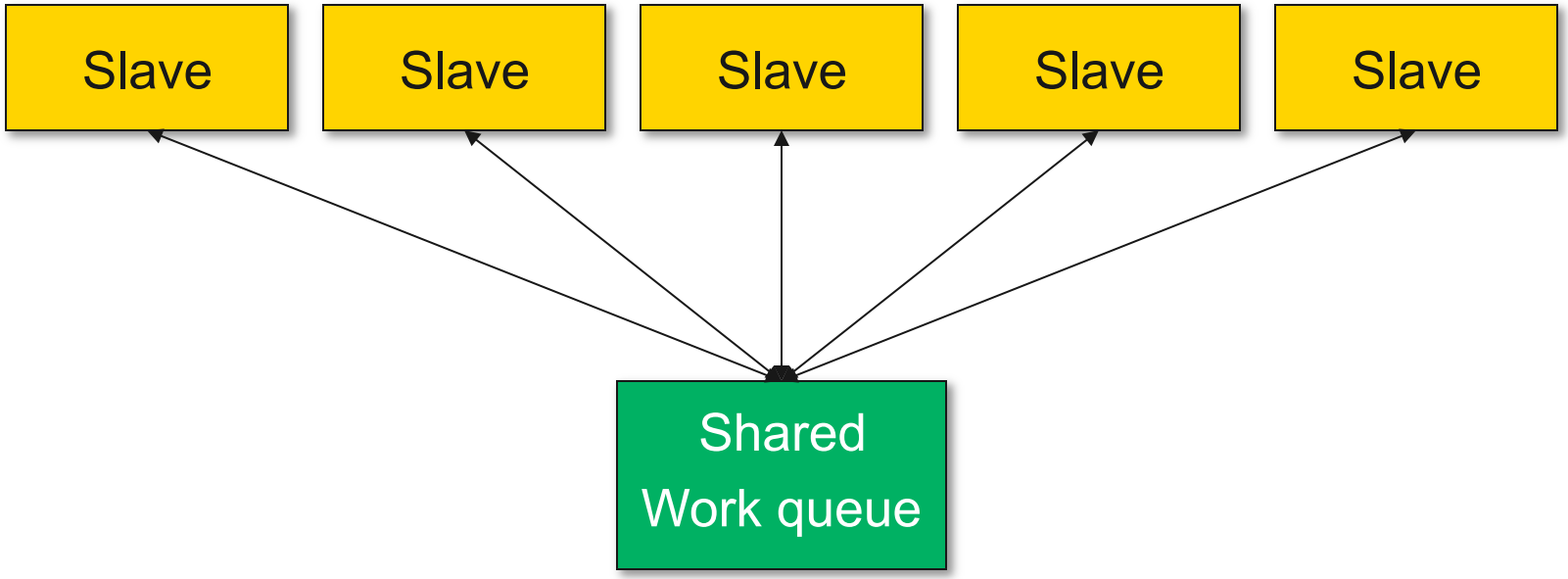


- Advantages
  - Automatic load balancing
- Disadvantages
  - Scalability - master can become bottleneck
- Wrinkles
  - Slaves may create new work
  - Multiple work types and priorities that impose work flow

The ADLB Vision

- No explicit master for load balancing; slaves make calls to ADLB library; those subroutines access local and remote data structures (remote ones via MPI).
- Simple Put/Get interface from application code to distributed work queue hides most MPI calls
  - Advantage: multiple applications may benefit
  - Wrinkle: variable-size work units, in Fortran, introduce some complexity in memory management
- Proactive load balancing in background
  - Advantage: application never delayed by search for work from other slaves
  - Wrinkle: scalable work-stealing algorithms not obvious

The ADLB Model (no master)



- Doesn't really change algorithms in slaves
- Not a new idea (e.g. Linda)
- But need scalable, portable, distributed implementation of shared work queue
  - MPI complexity hidden here.

API for a Simple Programming Model

- Basic calls
  - ADLB_Init(num_servers, am_server, app_comm)
  - ADLB_Server()
  - ADLB_Put(type, priority, len, buf, answer_dest)
  - ADLB_Reserve(req_types, handle, len, type, prio, answer_dest)
  - ADLB_Ireserve(…)
  - ADLB_Get_Reserved(handle, buffer)
  - ADLB_Set_Done()
  - ADLB_Finalize()
- A few others, for tuning and debugging
  - ADLB_{Begin,End}_Batch_Put()
  - Getting performance statistics with ADLB_Get_info(key)

Parallel Sudoku Solver with ADLB

1	2				9			7
		3				6	1	
				7		8		
					5	3		
7		9	1		8	2		6
		5	6					
		1		9				
	6	7				1		
2			5				3	8

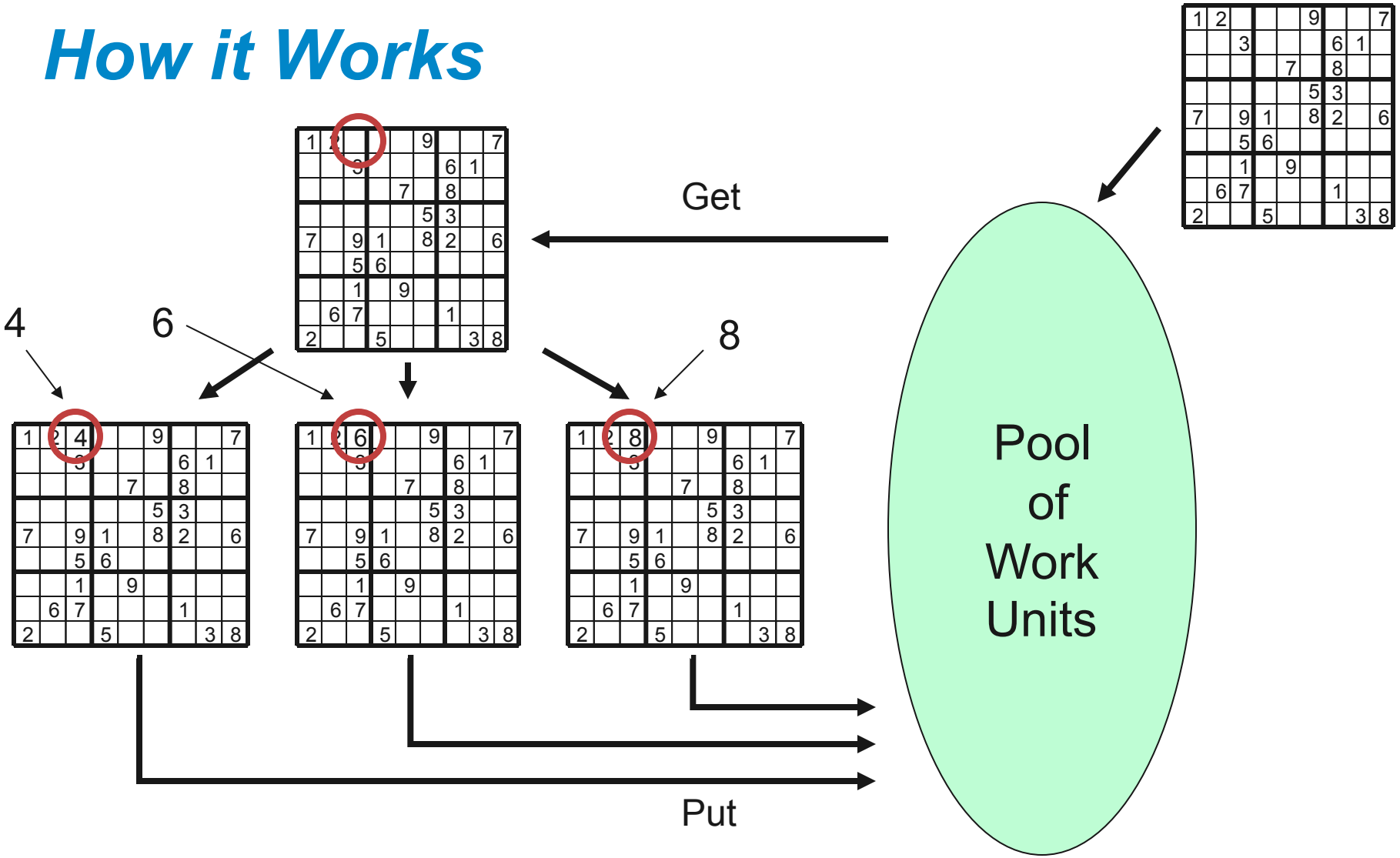
Work unit =

partially completed “board”

Program:

```
if (rank = 0)
    ADLB_Put initial board
ADLB_Get board (Reserve+Get)
while success  (else done)
    ooh
    find first blank square
    if failure  (problem solved!)
   print solution
   ADLB_Set_Done
    else
   for each valid value
       set blank square to value
       ADLB_Put new board
   ADLB_Get board
end while
```

How it Works



- After initial Put, all processes execute same loop (no master)

Optimizing Within the ADLB Framework

- Can embed smarter strategies in this algorithm
  - ooh = “optional optimization here”, to fill in more squares
  - Even so, potentially a *lot* of work units for ADLB to manage
- Can use priorities to address this problem
  - On ADLB_Put, set priority to the number of filled squares
  - This will guide depth-first search while ensuring that there is enough work to go around
    - *How one would do it sequentially*
- Exhaustion automatically detected by ADLB (e.g., proof that there is only one solution, or the case of an invalid input board)

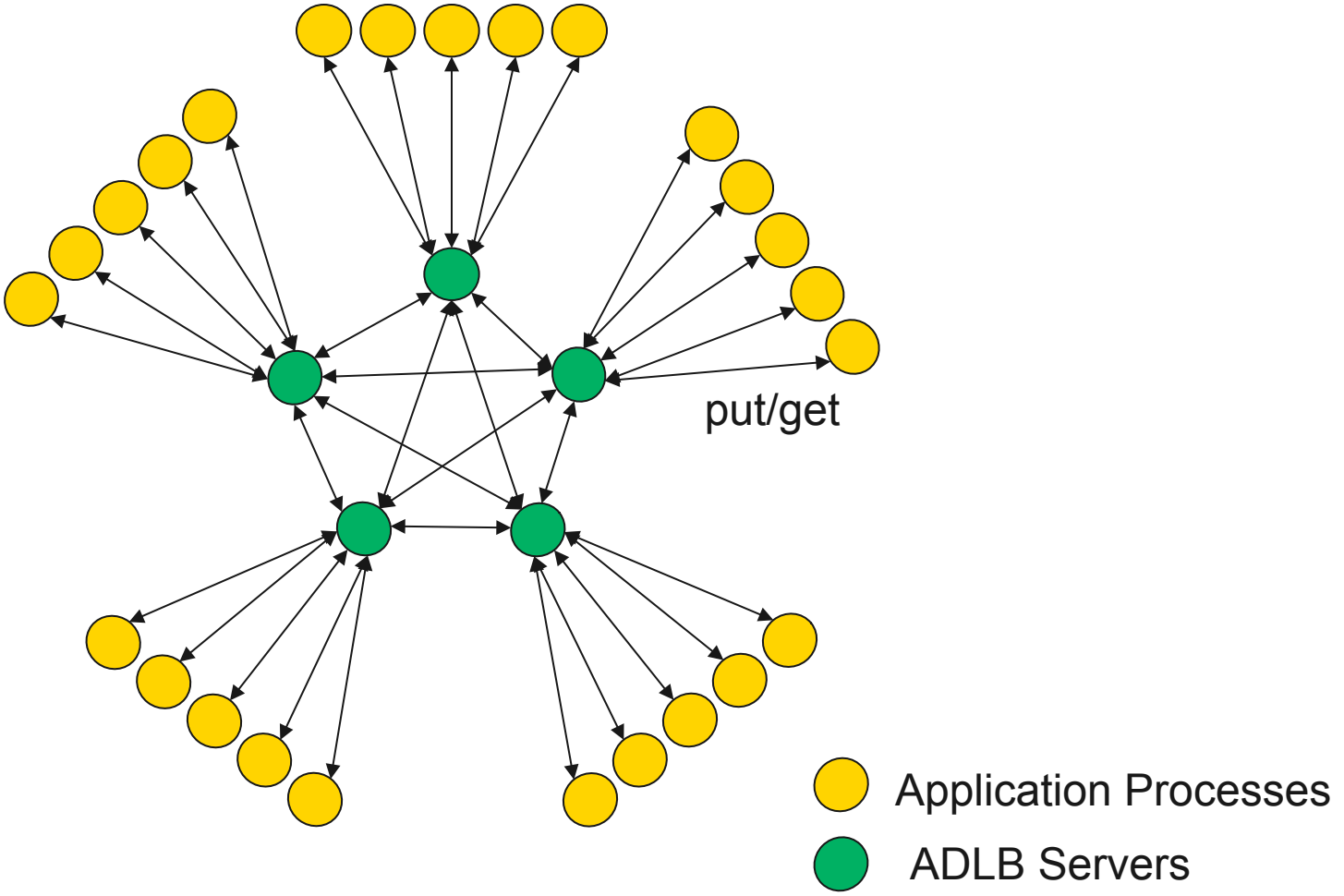
Experiments with GFMC/ADLB on BG/P

- Using GFMC to compute the binding energy of 14 neutrons in an artificial well (“neutron drop” = teeny-weeny neutron star)
- A weak scaling experiment

BG/P cores	ADLB Servers	Configs	Time (min.)	Efficiency (incl. serv.)
4K	130	20	38.1	93.8%
8K	230	40	38.2	93.7%
16K	455	80	39.6	89.8%
32K	905	160	44.2	80.4%

- Recent work: “micro-parallelization” needed for ^{12}C, OpenMP in GFMC.

How It Works



- Real numbers: 1000 servers out of 32,000 processors on BG/P
  - And recently introduced other communication paths

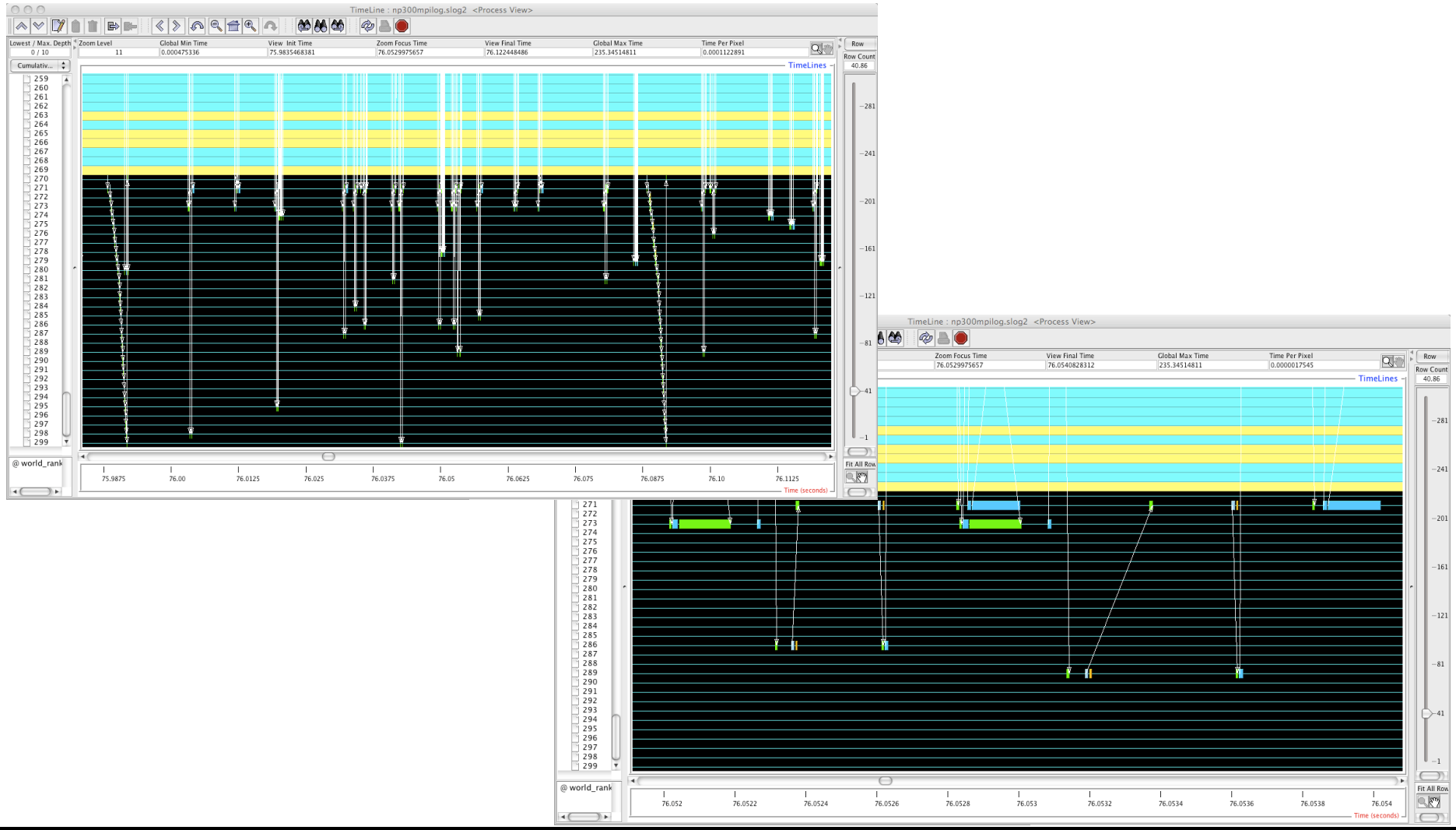
The ADLB Server Logic

- Main loop:
  - MPI_Iprobe for message in busy loop (emit diagnostics)
  - MPI_Recv message
  - Process according to type (20 types)
    - *Update status vector of work stored on remote servers*
    - *Manage work queue and request queue*
    - *(may involve posting MPI_Isends to isend queue)*
  - MPI_Test all requests in isend queue
  - Return to top of loop
- The status vector replaces single master or shared memory
  - Circulates every .1 second at high priority

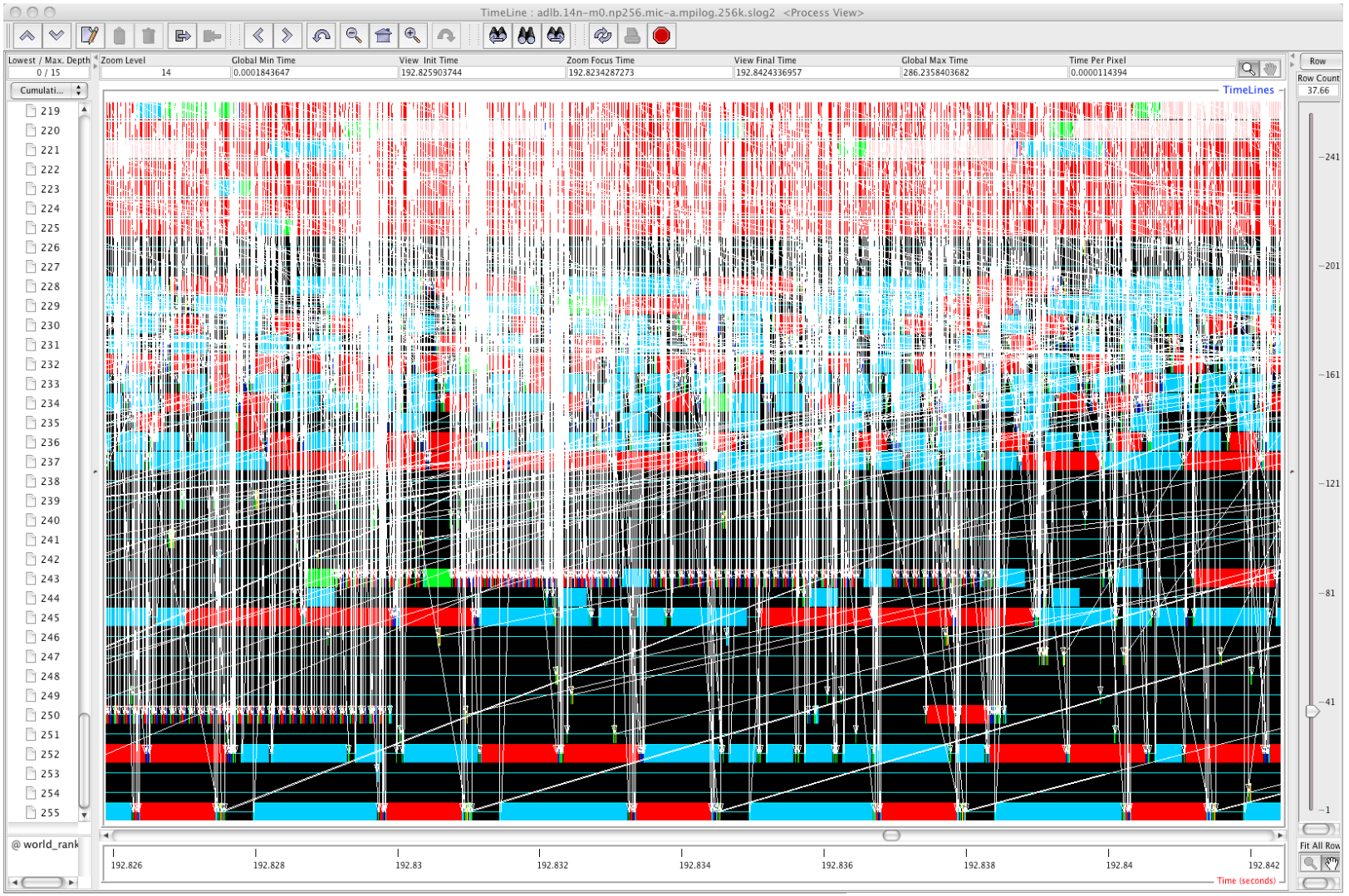
ADLB Uses Multiple MPI Features

- ADLB_Init returns separate application communicator, so application can use MPI for its own purposes if it needs to.
- Servers are in MPI_Iprobe loop for responsiveness.
- MPI_Datatypes for some complex, structured messages (status)
- Servers use nonblocking sends and receives, maintain queue of active MPI_Request objects.
- Queue is traversed and each request kicked with MPI_Test each time through loop; could use MPI_Testany.
- Client side uses MPI_Ssend to implement ADLB_Put in order to conserve memory on servers, MPI_Send for other actions.
- Servers respond to requests with MPI_Rsend since MPI_Irecvs are known to be posted by clients before requests.
- MPI provides portability: laptop, Linux cluster, SiCortex, BG/P
- MPI profiling library is used to understand application/ADLB behavior.

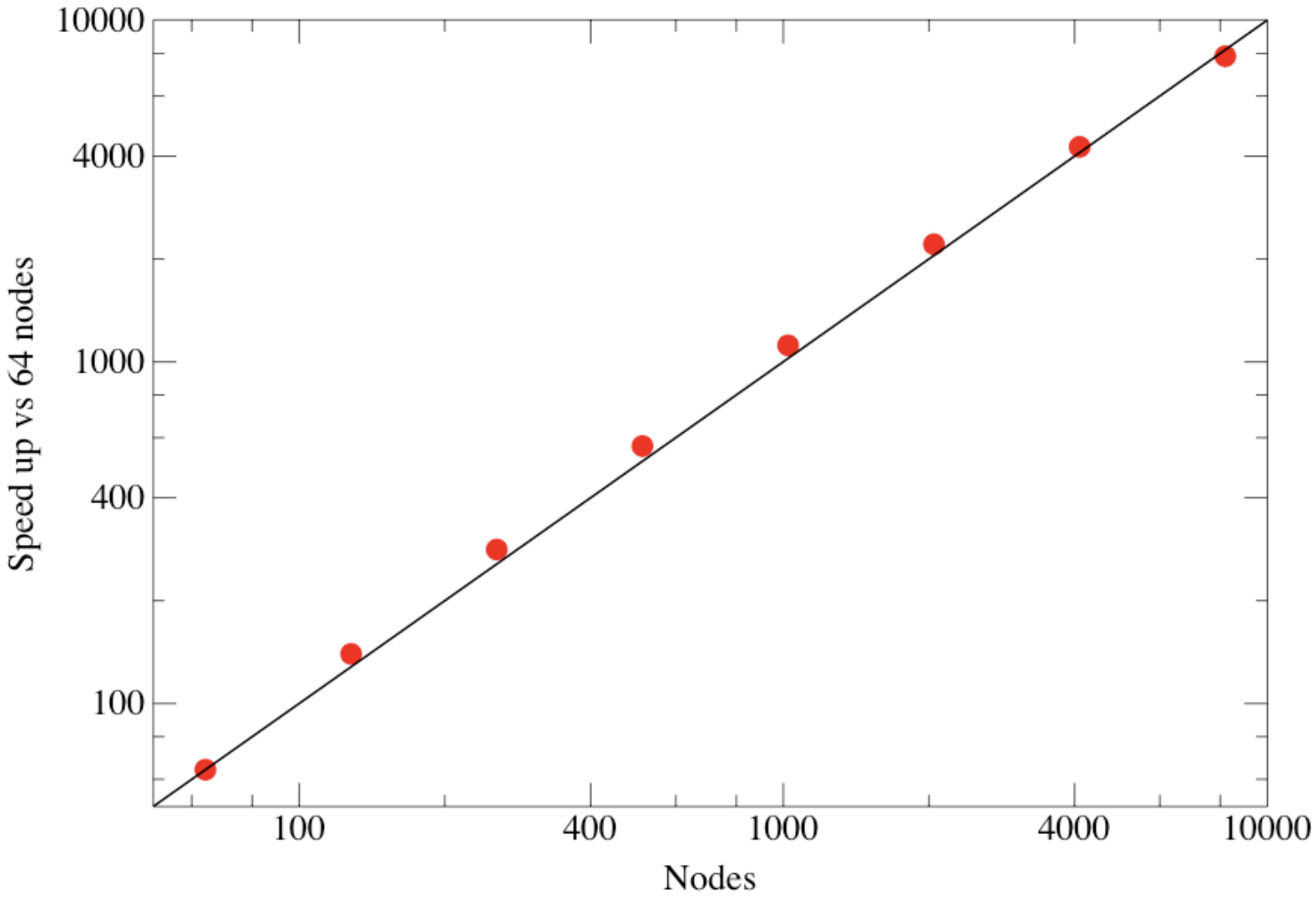
Looking at GFMC/ADLB with Jumpshot (in the good old days)



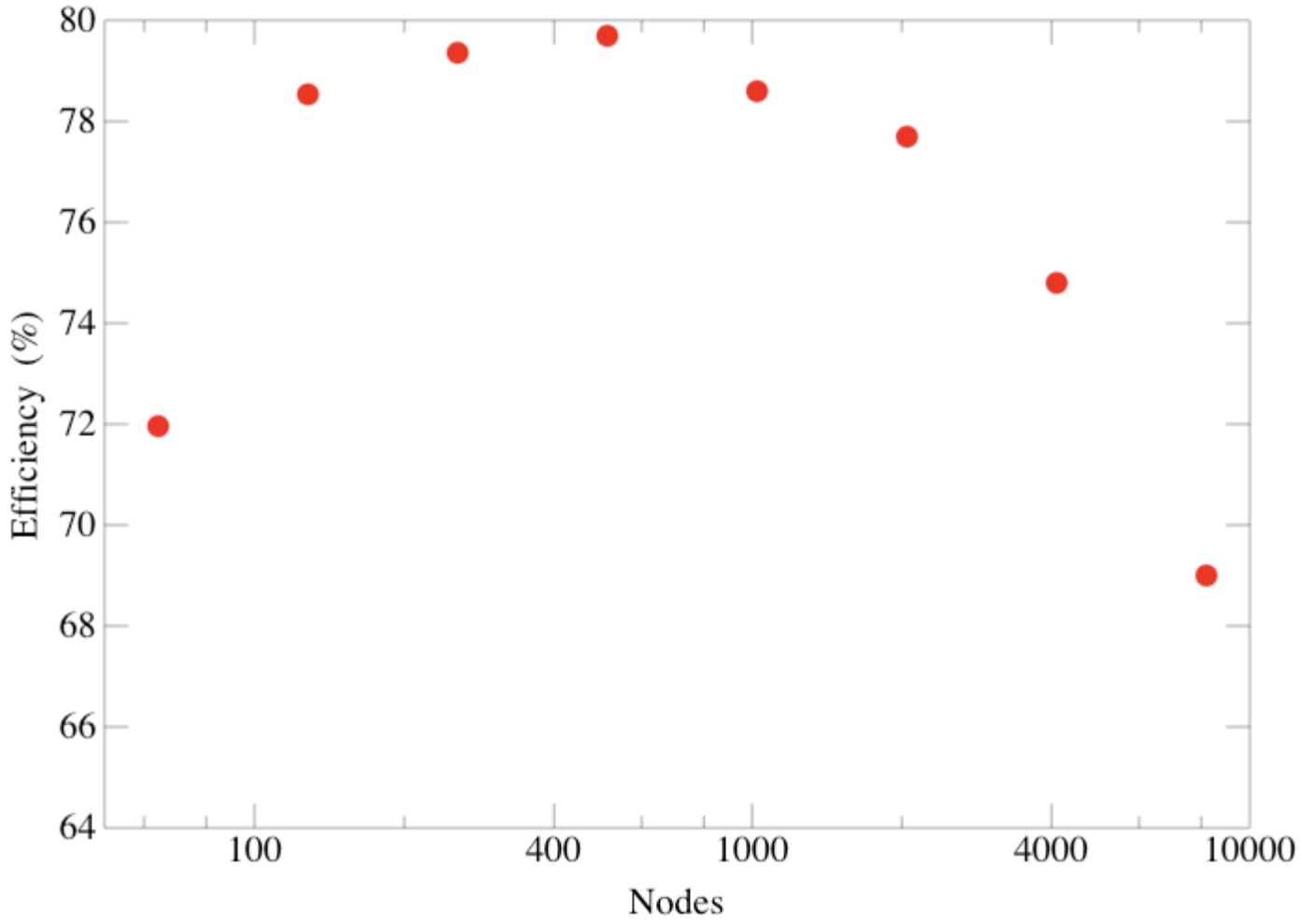
Things Can Get Worse at Larger Scale



Experiments Last Fall



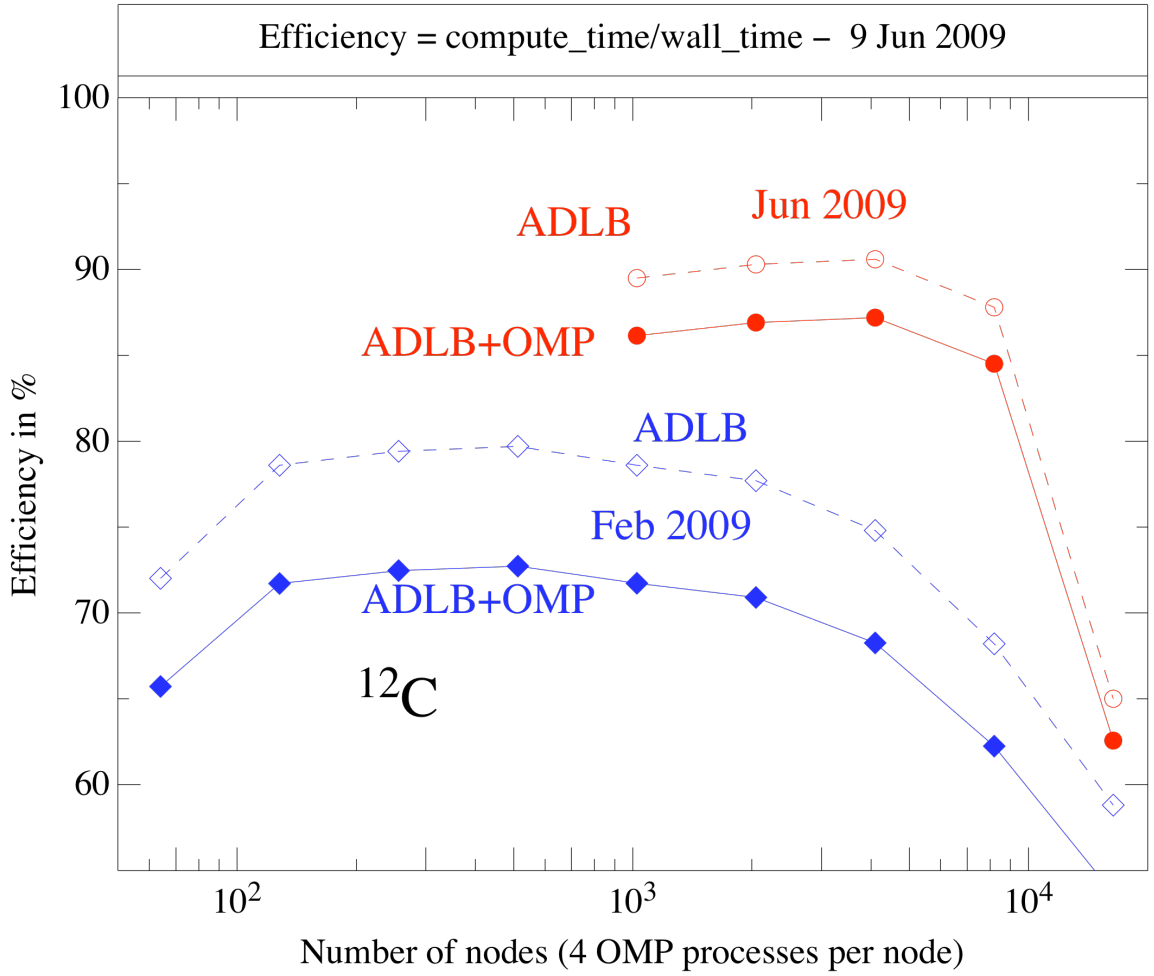
Experiments Last Fall



Good News – Bad News

RESULTS SO FAR

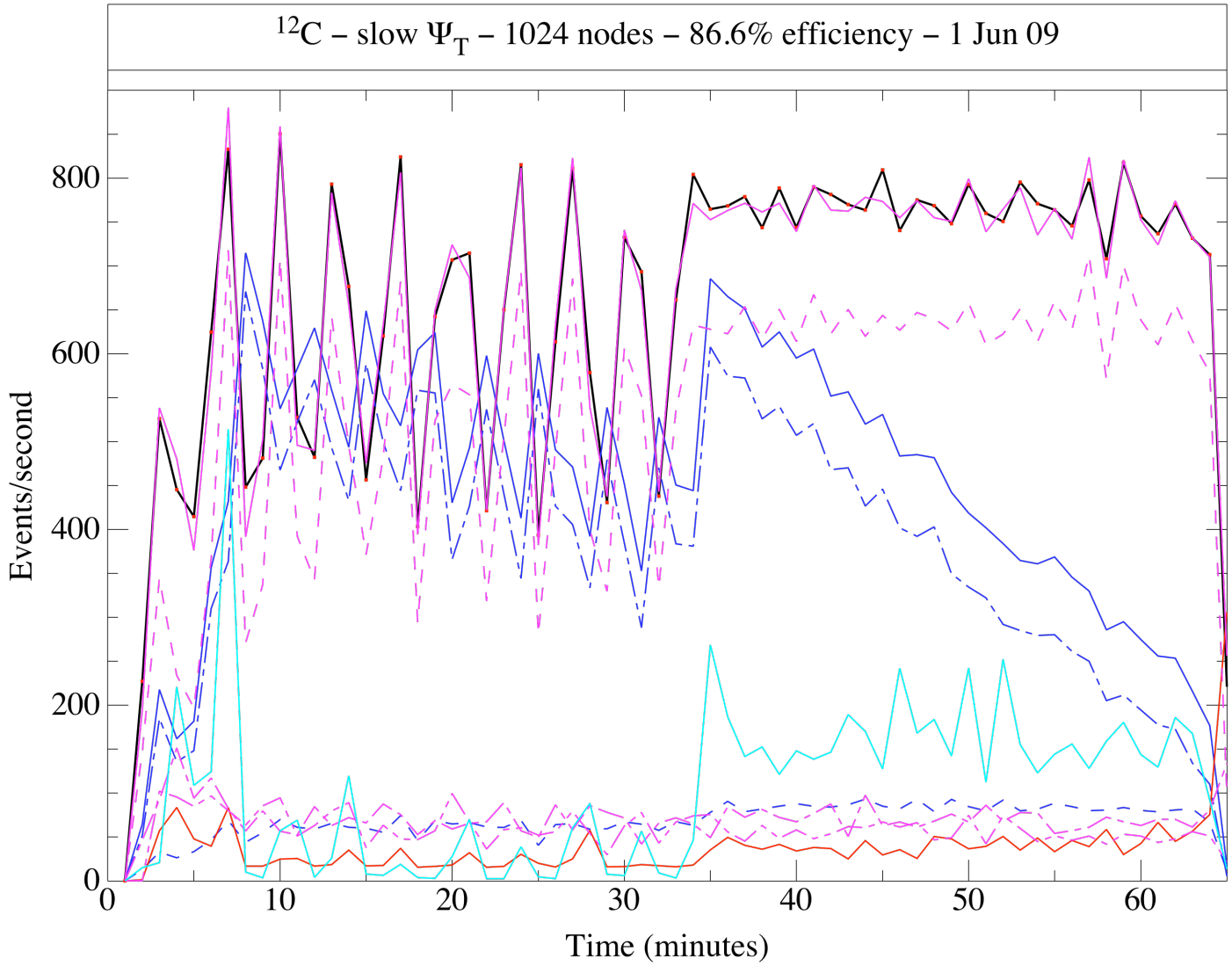
ADLB performance is very good up to 8192 nodes (32,768 cores)



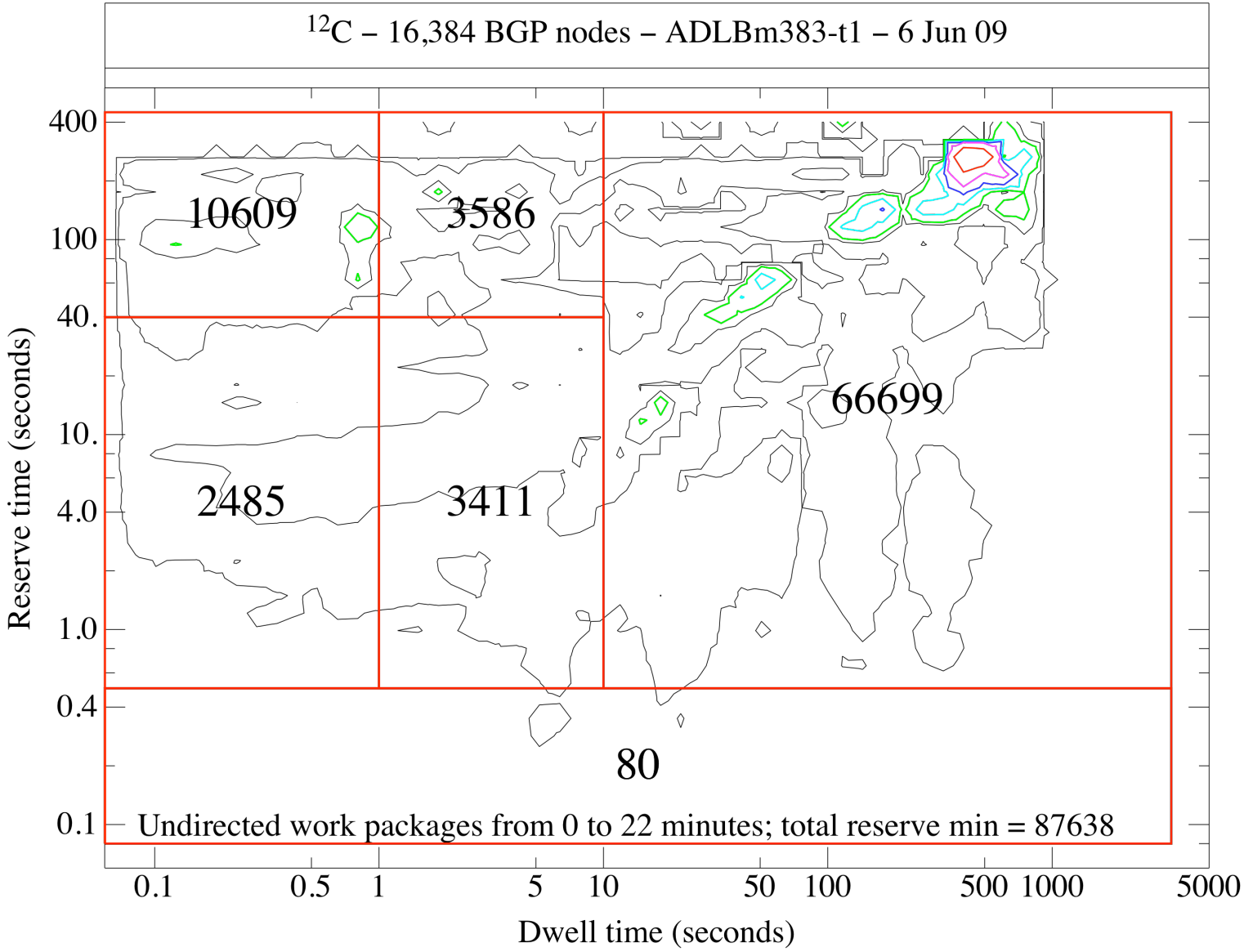
The Need for Tools

- *Understanding* the behavior of the coupled application/library is difficult.
  - (Friendly) finger pointing has led to advances
- Big problem: everything works fine at 8,000 processors and below
  - So testing and debugging is cumbersome at best
- Jumpshot not really usable at very large scale
- Statistics point to problems, but not to solutions, since time-varying behavior is not captured in averages
- Large amounts of debugging and monitoring output cause their own problems
- We are still developing tools for understanding behavior
  - At large scale
  - That varies over time

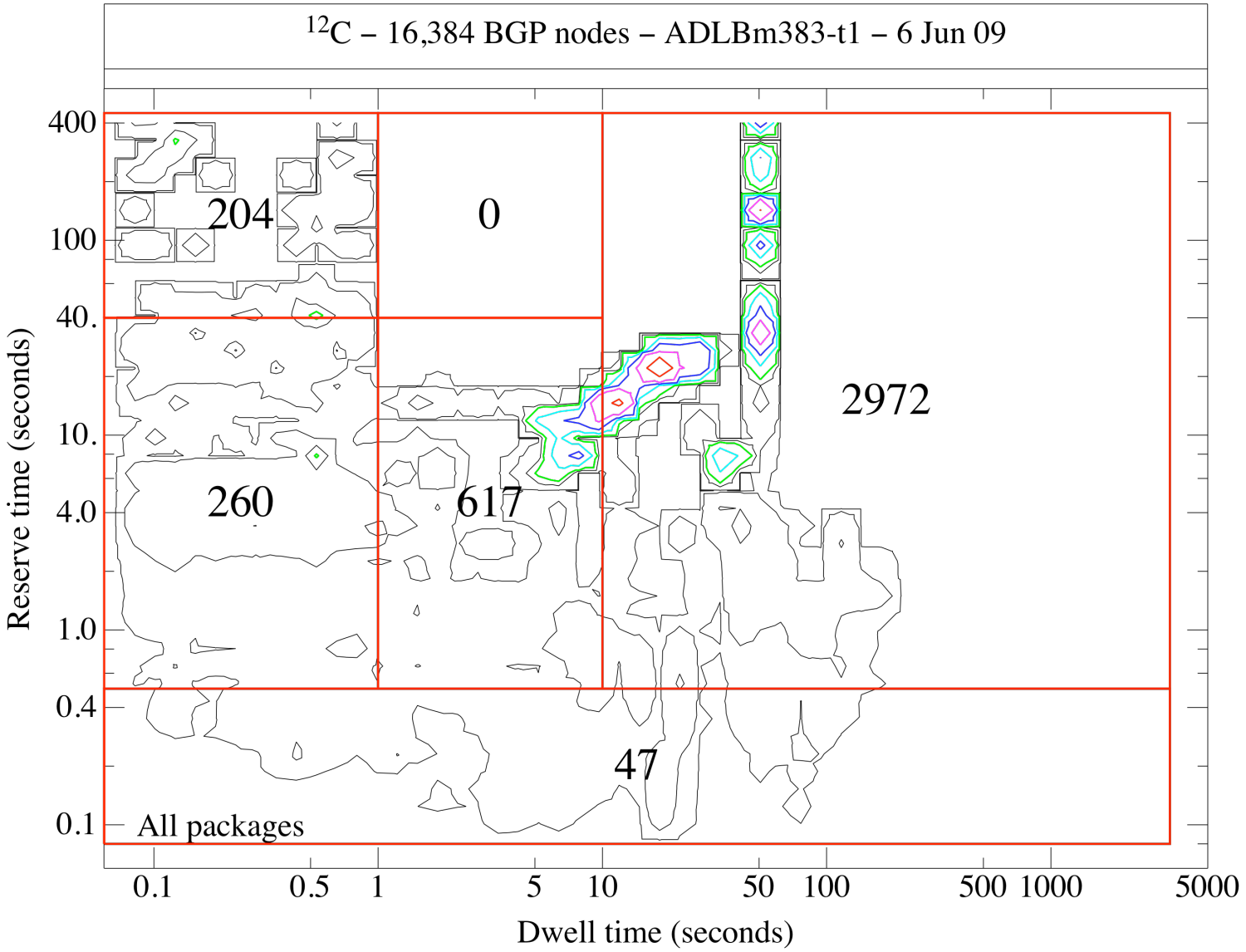
Plotting Statistics Over Time



Tracking Anomalies



Problem Apparently Fixed



Multiple Load-Balancing Regimes

- The original objective was to do balancing of processing load
- Much of the last year has been spent on balancing of the memory load
  - Work units may to be moved from server to server
  - Even proactively
- We may now be having problems that can only be solved by balancing of the message-passing load.

The "Official" Questions

- What are the main accomplishments since the last meeting? Is your Year-3 plan well on track?
  - Main accomplishments
    - *Conversion of GFMC application code to use OpenMP*
    - *First large scale ^{12}C calculations*
    - *Scaling to 8 racks on BG/P*
  - Grappling with scaling problems going from 8K to 32K processes
- What are the aspects of your science that require high-performance computing? OR What problems in high performance computing are you working on in general?
  - Problems in high-performance computing:
    - *How to exploit HPC computers with 100,000 processors*
    - *How to simplify application programming in general*
    - *ADLB is a demonstration of what can be achieved with a semi-specialized library*

The Questions (cont.)

- What are the major computational issues? Are there any questions you would like to bring to the attention of our CS/AM collaborators? OR Are there general capabilities of your computer science work that might be of interest to other physicists than the ones you are currently working with?
  - ADLB is a general-purpose library which we are developing / testing / debugging / tuning in the context of GFMC
  - But worth a look for any application in which the parallelism is task-based and there is little communication among the tasks.
  - ADLB Web site: http://www.cs.mtsu.edu/~rbutler/adlb
- What is the detailed roadmap of your project for the remaining part of Year-3 and Year-4? Could you sketch the work plan for Year 5?
  - Near-term: get to 16 racks, maybe 32, with good efficiency scaling
  - Better tools for understanding behavior and performance
  - Far-term: explore use of MPI RMA to further distribute work
- Are there any "showcase" (i.e., of Nature/Science caliber) physics and computational questions that you are hoping to answer in Years 3 and 4?
  - It's up to Steve!

Conclusions

- ADLB is a research project working its way toward being useful general-purpose software.
- More users sought, especially those with more straightforward applications than GFMC!
- Its point is to explore whether extreme scalability in an application can be achieved without extreme complexity in application code.
- Much has been learned, understood, and achieved in the first few years.
- But we are not finished.
  - Which is good, in a way ☺.