FATCOP: A Mixed Integer Program Solver

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The "Seymour Problem"

- Set covering problem used in proof of four color theorem
- Solution never demonstrated!
- CPLEX and Condor (2 option files)
- Running since June 23, 1999
- Currently >231 days CPU time per job
- (5.6 million nodes; 1.1 million nodes)

MIP formulation

minimize $c^T x$

subject to $Ax \leq b$

$l \leq x \leq u$

and some x_j integer

Problems are specified by application convenient format - GAMS, AMPL, or MPS

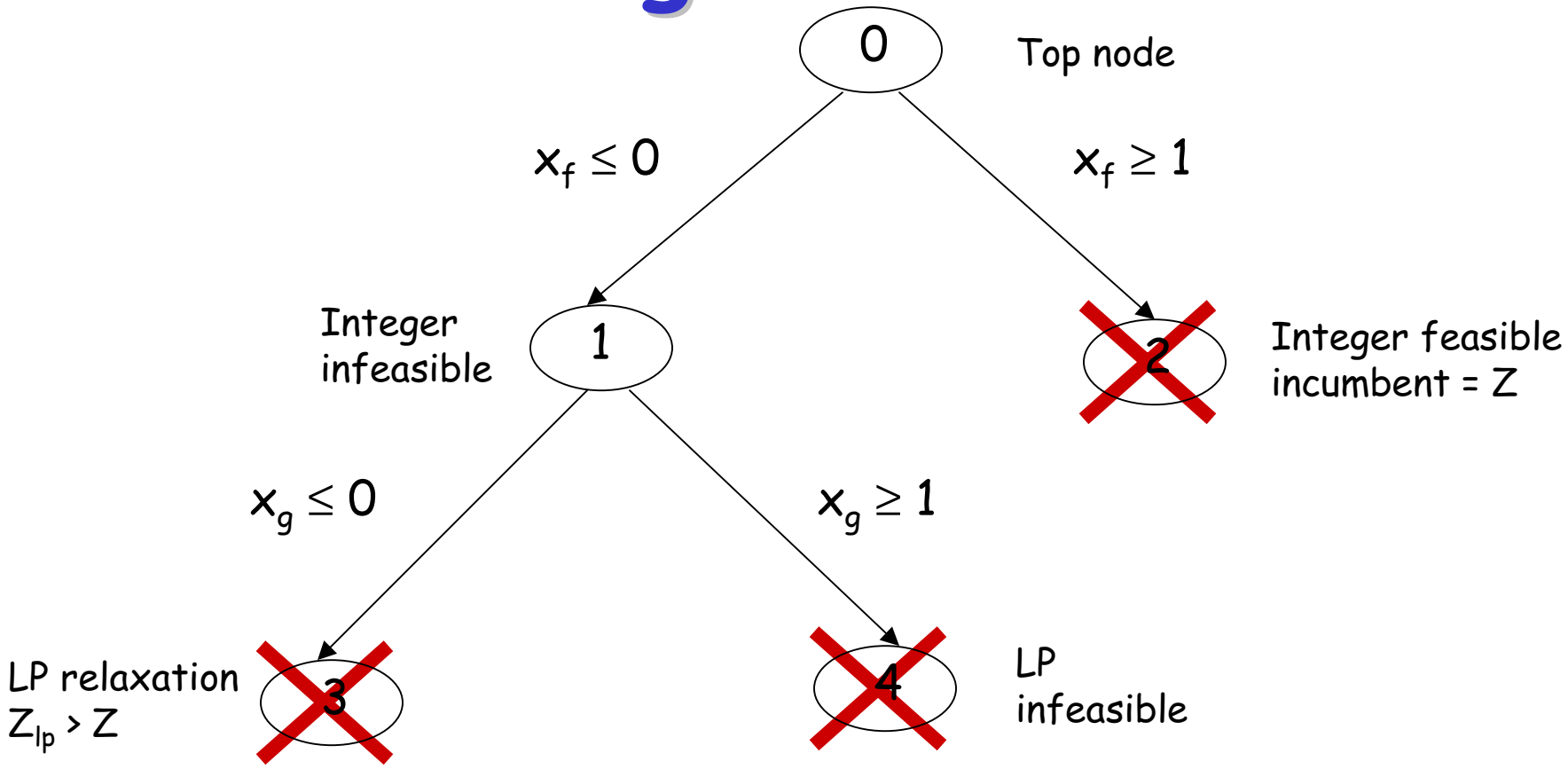
Example applications

- Airline crew scheduling
- Radiosurgery treatment plans
  - how to zap tumors and avoid organs
- Portfolio optimization
- Facility location
  - where to put the Perrier plant
- Process design

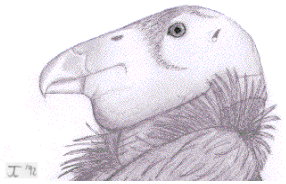
FATCOP Summary

- Branch and Bound: LP relaxations
- PVM and Condor
  - opportunistic environment
  - portable parallel programming
- Features:
  - Master-worker implementation
  - Fault tolerant: task exit, host suspend
  - MPS file or GAMS or AMPL input

Branch-and-Bound Algorithm

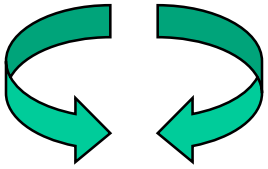


Condor and PVM

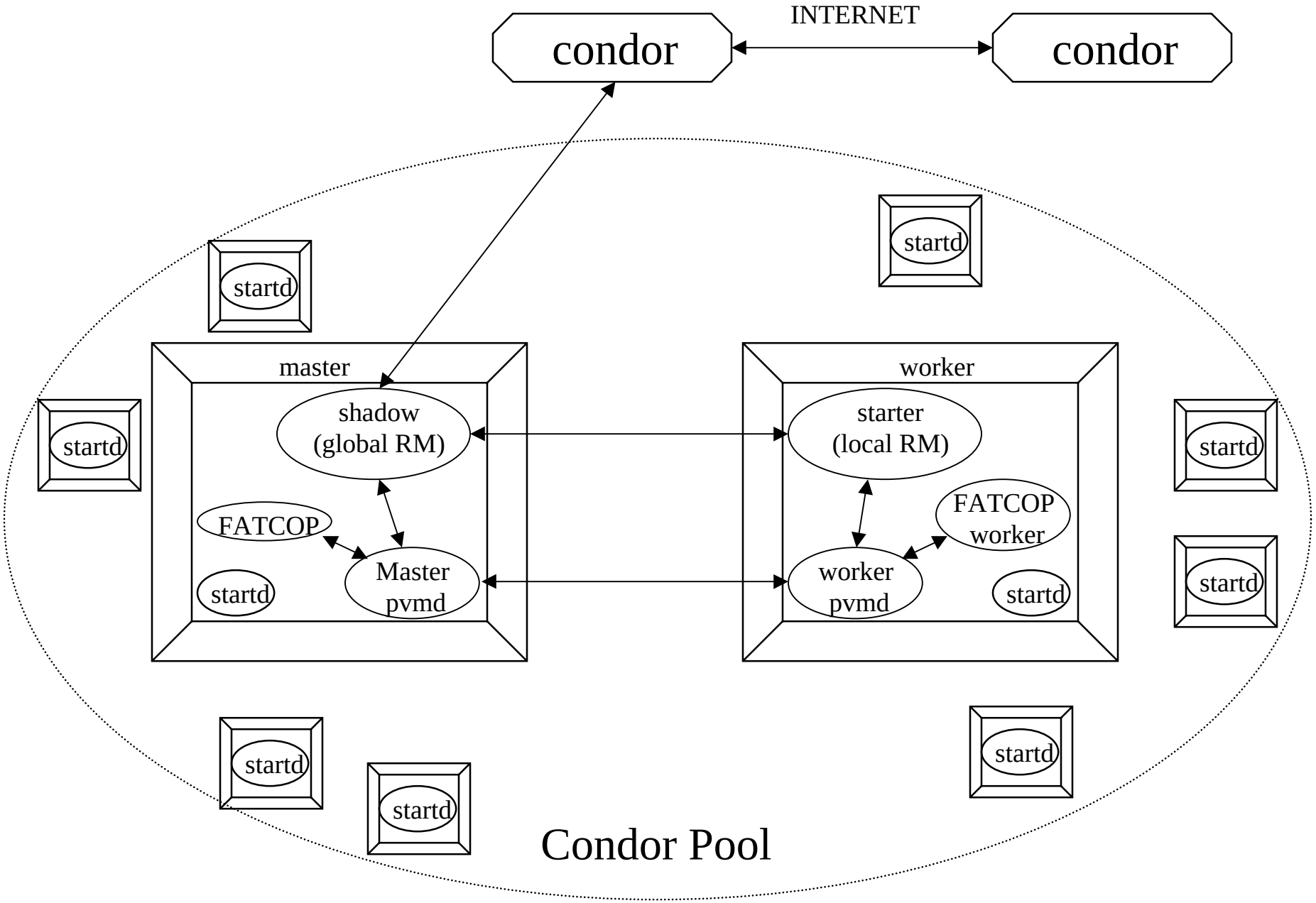


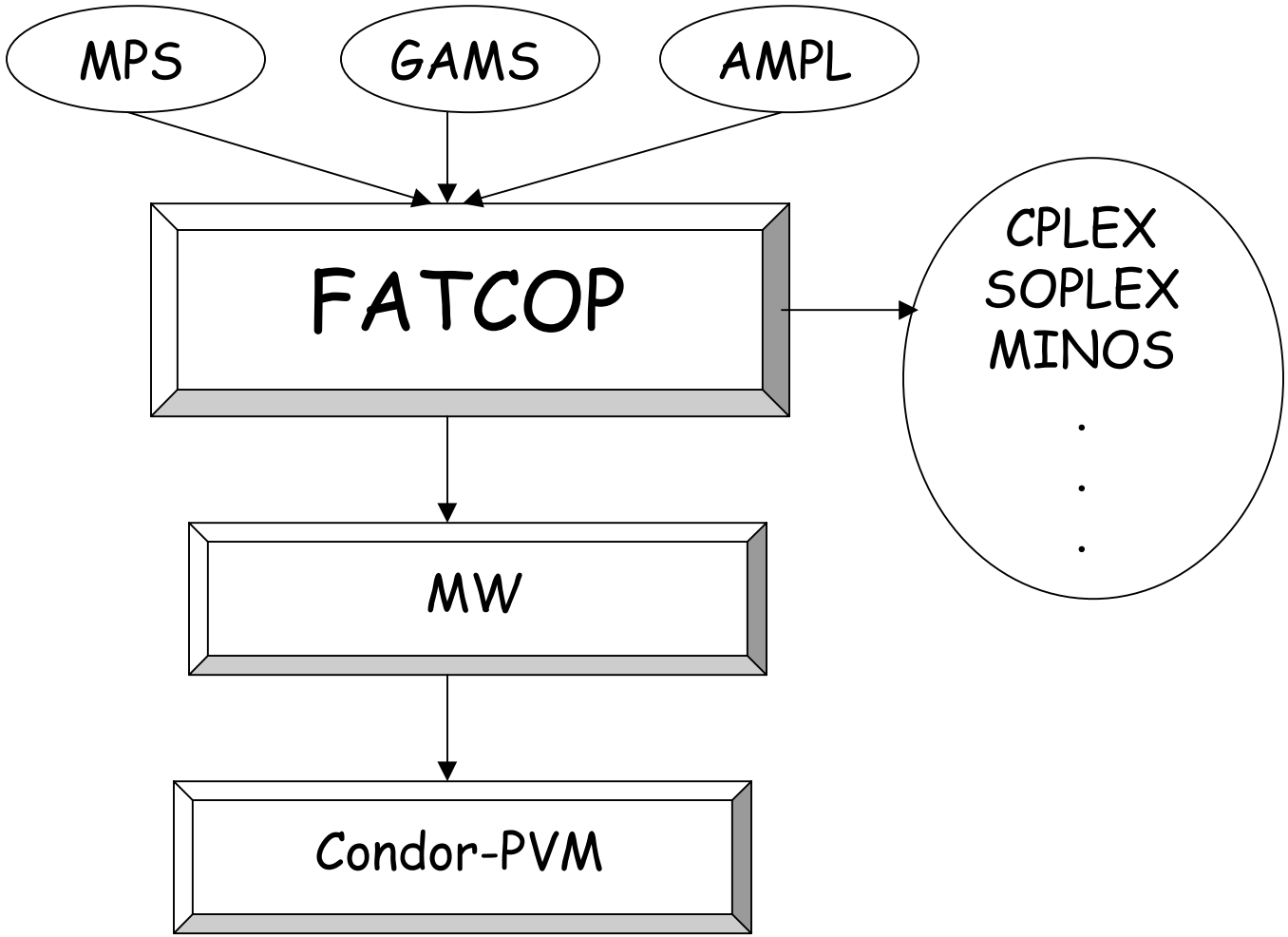
- **Condor**: a distributed resource management system
- Manages large heterogeneous clusters of UNIX workstations
- Design motivated to use ‘idle’ capacity for long-running, computation-intensive jobs

- **PVM** (parallel virtual machine): software allowing heterogeneous network of computers to appear as a single concurrent computational resource
- Unified framework for parallel program development

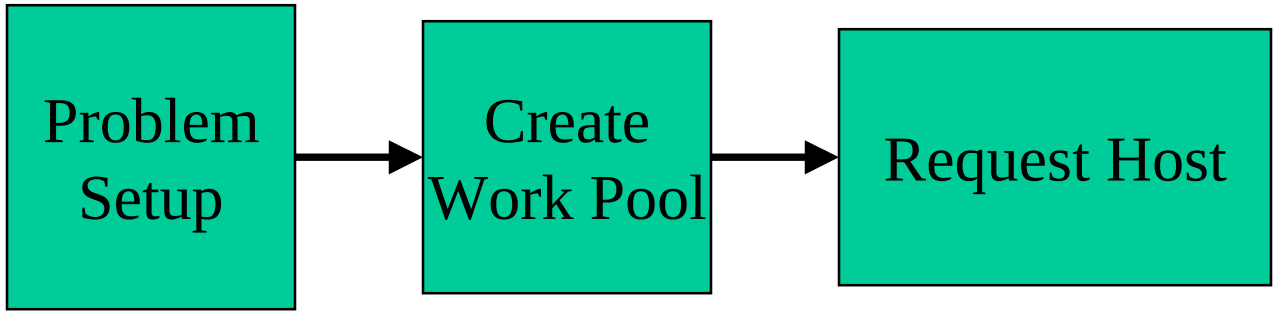


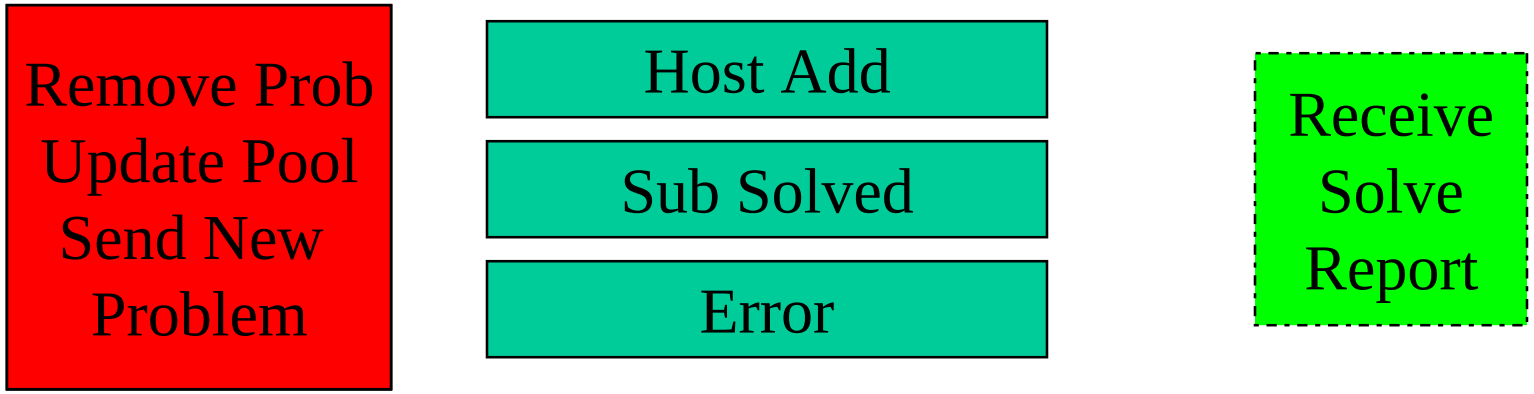
- **PVM and Condor** perfectly matched
- Framework to run parallel applications in a distributed opportunistic environment


INTERNET
condor
condor
startd
startd
startd
master
shadow
(global RM)
FATCOP
Master
pvmd
startd
worker
starter
(local RM)
FATCOP
worker
worker
pvmd
startd
startd
startd
startd
startd
startd
Condor Pool

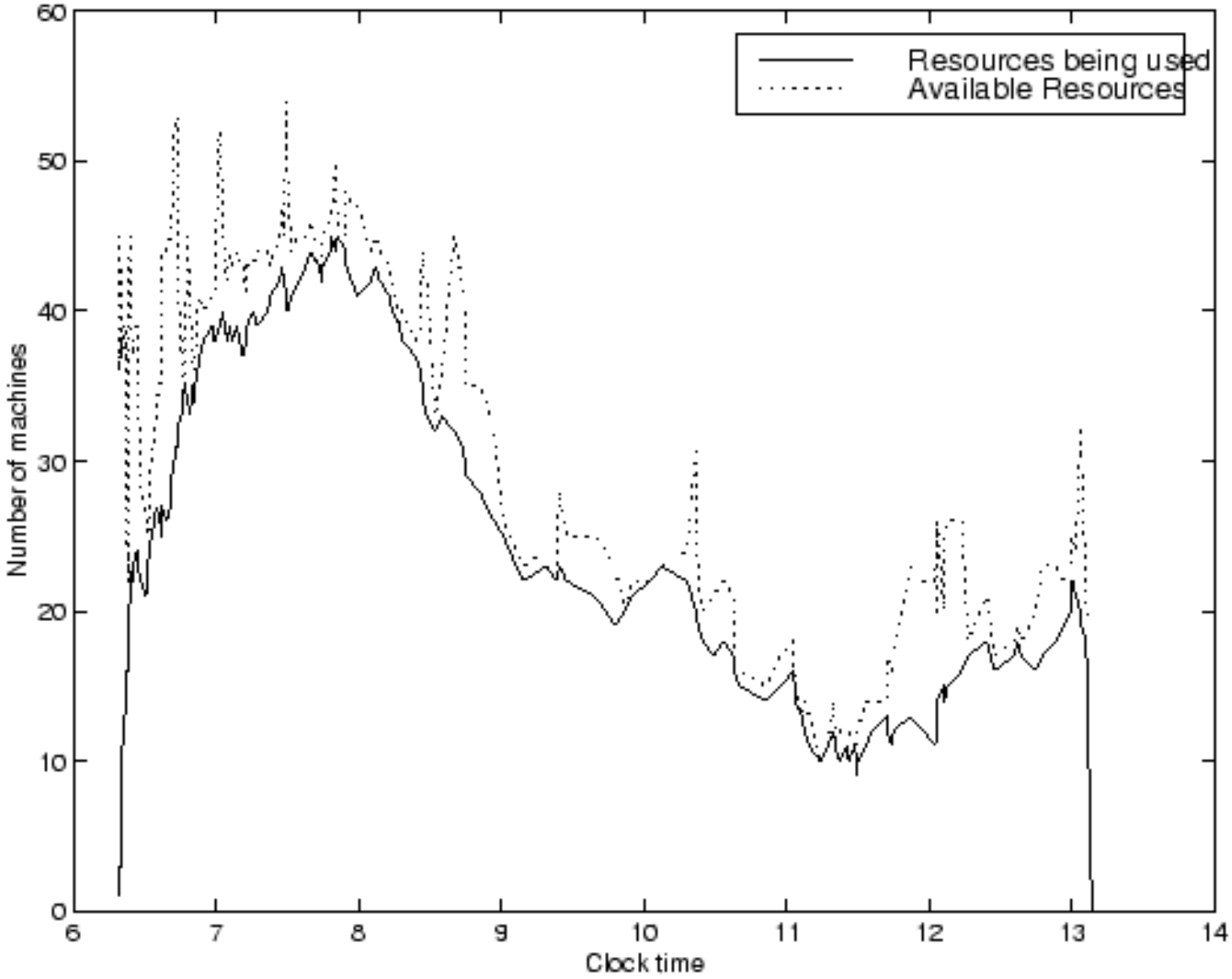

MPS
GAMS
AMPL
FATCOP
CPLEX
SOPLEX
MINOS
.
.
.
MW
Condor-PVM

Operation

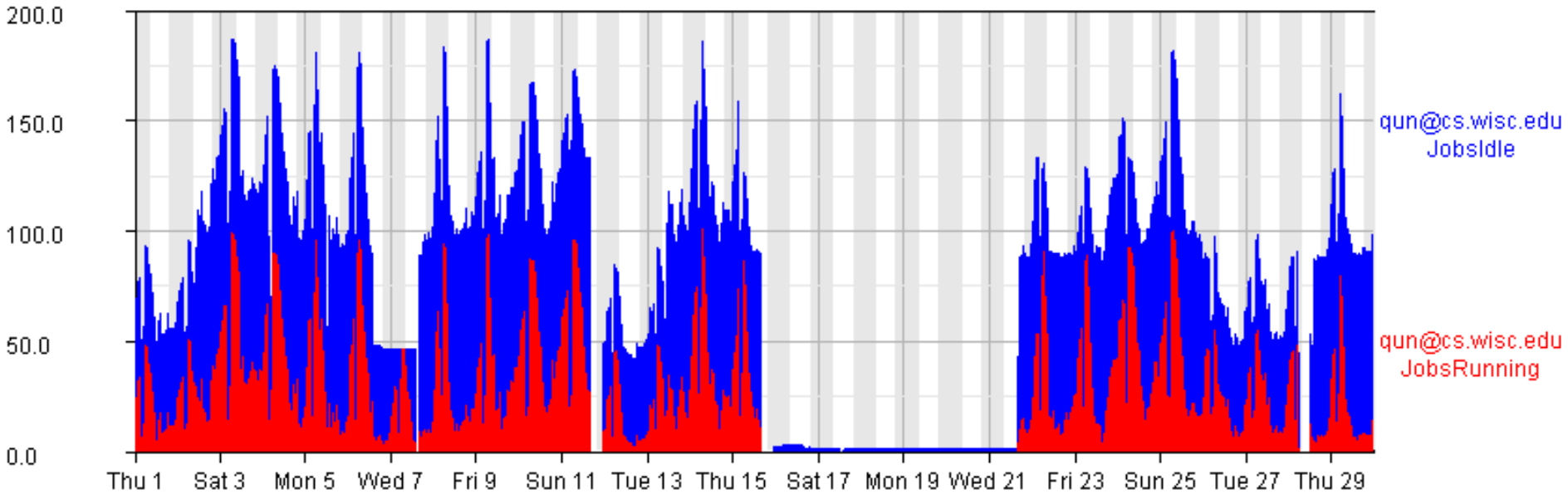

Problem Setup
Create Work Pool
Request Host


Remove Prob
Update Pool
Send New Problem
Host Add
Sub Solved
Error
Receive Solve Report

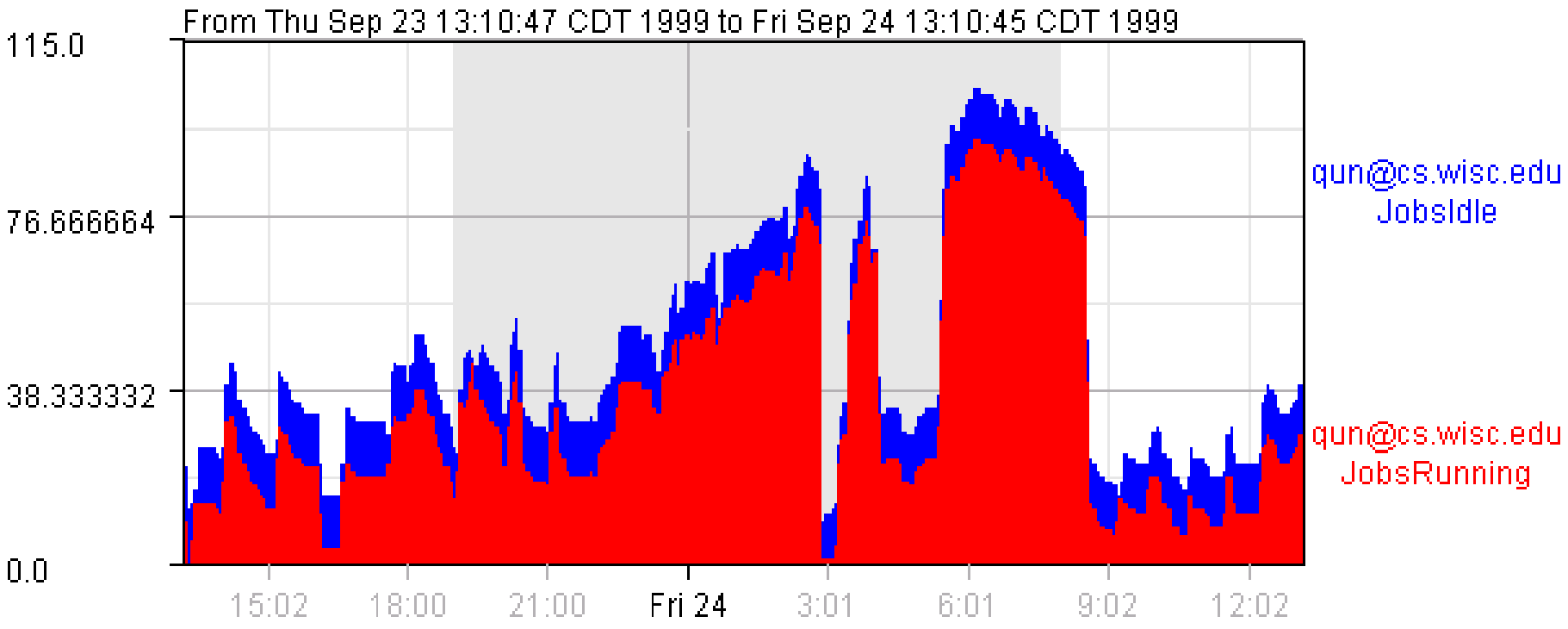
FATCOP: Single Job



FATCOP Monthly Log



FATCOP Daily Log



Optimization Capability

- Allows heterogeneous LP solvers, eg can use CPLEX and/or SOPLEX
- Preprocessing
- (Strong) branching, priorities
- Pseudocost node selection
- Cutting planes
- User defined heuristics

Simple Interfaces

- Write the heuristic code in C/C++
  - Perform heuristics at root node
  - Rounding heuristics at any node
  - Searching heuristics at integer nodes
- Turn on option "perform heuristics"
- Load the dll at solve time

Product Design Problem

- Maximize market share by choosing a product profile
- Product has 7 attributes, and each attribute has 7 levels, 100 customers
- MIP cannot solve to optimality
- Genetic algorithm is performed at root node - how good is its solution?

Product Design: MIP + GA

Relative Gap %	Nodes with GA	Nodes w/out GA
20	1,178	864,448
15	2,230	>1,000,000
10	6,506	>1,000,000
5	37,224	>1,000,000
0	137,866	>1,000,000

Future Work

- How to steer the optimization process?
  - human/computer interactive optimization
  - utilize problem specific information
- Fly-in FATCOP / FATCOP for industry?

www.cs.wisc.edu/~ferris

www.cs.wisc.edu/~ferris/fatcop.html