So, You Need to Look at a New Application …

Scenarios:

- New application development
- Analyze/Optimize external application
- Suspected bottlenecks

First goal: overview of …

- Communication frequency and intensity
- Types and complexity of communication
- Source code locations of expensive MPI calls
- Differences between processes

Basic Principle of Profiling MPI

Intercept all MPI API calls

- Using wrappers for all MPI calls

Aggregate statistics over time

- Number of invocations
- Data volume
- Time spent during function execution

Multiple aggregations options/granularity

- By function name or type
- By source code location (call stack)
- By process rank

mpiP: Efficient MPI Profiling

Open source MPI profiling library

- Developed at LLNL, maintained by LLNL & ORNL
- Available from sourceforge
- Works with any MPI library

Easy-to-use and portable design

- Relies on PMPI instrumentation
- No additional tool daemons or support infrastructure
- Single text file as output
- Optional: GUI viewer

Running with mpiP 101 / Experimental Setup

mpiP works on binary files

- Uses standard development chain
- Use of “-g” recommended

Run option 1: Relink

- Specify libmpi.a/.so on the link line
- Portable solution, but requires object files

Run option 2: library preload

- Set preload variable (e.g., LD_PRELOAD) to mpiP
- Transparent, but only on supported systems

Running with mpiP 101 / Running

```
bash-3.2$ srun –n4 smg2000
mpiP:
mpiP:
mpiP: mpiP V3.1.2 (Build Dec 16 2008/17:31:26)
mpiP: Direct questions and errors to mpip-help@lists.sourceforge.net
mpiP:
Running with these driver parameters:
  (nx, ny, nz)    = (60, 60, 60)
  (Px, Py, Pz)    = (4, 1, 1)
  (bx, by, bz)    = (1, 1, 1)
  (cx, cy, cz)    = (1.000000, 1.000000, 1.000000)
  (n_pre, n_post) = (1, 1)
  dim             = 3
  solver ID       = 0
=============================================
Struct Interface:
=============================================
Struct Interface:
  wall clock time = 0.075800 seconds
  cpu clock time  = 0.080000 seconds
=============================================
Setup phase times:
=============================================
SMG Setup:
  wall clock time = 1.473074 seconds
  cpu clock time  = 1.470000 seconds
=============================================
Solve phase times:
=============================================
SMG Solve:
  wall clock time = 8.176930 seconds
  cpu clock time  = 8.180000 seconds

Iterations = 7
Final Relative Residual Norm = 1.459319e-07

mpiP:
mpiP: Storing mpiP output in [./smg2000-p.4.11612.1.mpiP].
mpiP:
bash-3.2$
```

Header

Output File

mpiP 101 / Output – Metadata

```
@ mpiP
@ Command : ./smg2000-p -n 60 60 60
@ Version                  : 3.1.2
@ MPIP Build date          : Dec 16 2008, 17:31:26
@ Start time               : 2009 09 19 20:38:50
@ Stop time                : 2009 09 19 20:39:00
@ Timer Used               : gettimeofday
@ MPIP env var             : [null]
@ Collector Rank           : 0
@ Collector PID            : 11612
@ Final Output Dir         : .
@ Report generation        : Collective
@ MPI Task Assignment      : 0 hera27
@ MPI Task Assignment      : 1 hera27
@ MPI Task Assignment      : 2 hera31
@ MPI Task Assignment      : 3 hera31
```

mpiP 101 / Output – Overview

```
---------------------------------------------------------------
@--- MPI Time (seconds) ---------------------------------------
---------------------------------------------------------------
Task    AppTime    MPITime     MPI%
   0       9.78       1.97    20.12
   1        9.8       1.95    19.93
   2        9.8       1.87    19.12
   3       9.77       2.15    21.99
   *       39.1       7.94    20.29
---------------------------------------------------------------
```

mpiP 101 / Output – Callsites

```
---------------------------------------------------------------------------
@--- Callsites: 23 ---------------------------------------------------------
---------------------------------------------------------------------------
 ID Lev File/Address        Line Parent_Funct                    MPI_Call
  1   0 communication.c     1405 hypre_CommPkgUnCommit           Type_free
  2   0 timing.c             419 hypre_PrintTiming               Allreduce
  3   0 communication.c      492 hypre_InitializeCommunication   Isend
  4   0 struct_innerprod.c   107 hypre_StructInnerProd           Allreduce
  5   0 timing.c             421 hypre_PrintTiming               Allreduce
  6   0 coarsen.c            542 hypre_StructCoarsen             Waitall
  7   0 coarsen.c            534 hypre_StructCoarsen             Isend
  8   0 communication.c     1552 hypre_CommTypeEntryBuildMPI     Type_free
  9   0 communication.c     1491 hypre_CommTypeBuildMPI          Type_free
 10   0 communication.c      667 hypre_FinalizeCommunication     Waitall
 11   0 smg2000.c            231 main                            Barrier
 12   0 coarsen.c            491 hypre_StructCoarsen             Waitall
 13   0 coarsen.c            551 hypre_StructCoarsen             Waitall
 14   0 coarsen.c            509 hypre_StructCoarsen             Irecv
 15   0 communication.c     1561 hypre_CommTypeEntryBuildMPI     Type_free
 16   0 struct_grid.c        366 hypre_GatherAllBoxes            Allgather
 17   0 communication.c     1487 hypre_CommTypeBuildMPI          Type_commit
 18   0 coarsen.c            497 hypre_StructCoarsen             Waitall
 19   0 coarsen.c            469 hypre_StructCoarsen             Irecv
 20   0 communication.c     1413 hypre_CommPkgUnCommit           Type_free
 21   0 coarsen.c            483 hypre_StructCoarsen             Isend
 22   0 struct_grid.c        395 hypre_GatherAllBoxes            Allgatherv
 23   0 communication.c      485 hypre_InitializeCommunication   Irecv
---------------------------------------------------------------------------
```

mpiP 101 / Output – per Function Timing

```
---------------------------------------------------------------
@--- Aggregate Time (top twenty, descending, milliseconds) ---
---------------------------------------------------------------
Call                 Site       Time    App%    MPI%      COV
Waitall                10    4.4e+03   11.24   55.40     0.32
Isend                   3   1.69e+03    4.31   21.24     0.34
Irecv                  23        980    2.50   12.34     0.36
Waitall                12        137    0.35    1.72     0.71
Type_commit            17        103    0.26    1.29     0.36
Type_free               9       99.4    0.25    1.25     0.36
Waitall                 6       81.7    0.21    1.03     0.70
Type_free              15       79.3    0.20    1.00     0.36
Type_free               1       67.9    0.17    0.85     0.35
Type_free              20       63.8    0.16    0.80     0.35
Isend                  21         57    0.15    0.72     0.20
Isend                   7       48.6    0.12    0.61     0.37
Type_free               8       29.3    0.07    0.37     0.37
Irecv                  19       27.8    0.07    0.35     0.32
Irecv                  14       25.8    0.07    0.32     0.34
...
```

mpiP 101 / Output – per Function Message Size

```
---------------------------------------------------------------------
@--- Aggregate Sent Message Size (top twenty, descending, bytes) ------
---------------------------------------------------------------------
Call                 Site       Count      Total       Avrg  Sent%
Isend                   3      260044    2.3e+08        885  99.63
Isend                   7        9120   8.22e+05       90.1   0.36
Isend                  21        9120   3.65e+04          4   0.02
Allreduce               4          36        288          8   0.00
Allgatherv             22           4        112         28   0.00
Allreduce               2          12         96          8   0.00
Allreduce               5          12         96          8   0.00
Allgather              16           4         16          4   0.00
```

mpiP 101 / Output – per Callsite Timing

```
---------------------------------------------------------------------------
@--- Callsite Time statistics (all, milliseconds): 92 ---------------------
---------------------------------------------------------------------------
Name                 Site Rank  Count      Max     Mean      Min   App%   MPI%
Allgather              16    0      1    0.034    0.034    0.034   0.00   0.00
Allgather              16    1      1    0.049    0.049    0.049   0.00   0.00
Allgather              16    2      1     2.92     2.92     2.92   0.03   0.16
Allgather              16    3      1        3        3        3   0.03   0.14
Allgather              16    *      4        3      1.5    0.034   0.02   0.08

Allgatherv             22    0      1     0.03     0.03     0.03   0.00   0.00
Allgatherv             22    1      1    0.036    0.036    0.036   0.00   0.00
Allgatherv             22    2      1    0.022    0.022    0.022   0.00   0.00
Allgatherv             22    3      1    0.022    0.022    0.022   0.00   0.00
Allgatherv             22    *      4    0.036   0.0275    0.022   0.00   0.00

Allreduce               2    0      3    0.382    0.239    0.011   0.01   0.04
Allreduce               2    1      3     0.31    0.148    0.046   0.00   0.02
Allreduce               2    2      3    0.411    0.178    0.062   0.01   0.03
Allreduce               2    3      3     1.33    0.622    0.062   0.02   0.09
Allreduce               2    *     12     1.33    0.297    0.011   0.01   0.04

...
```

mpiP 101 / Output – per Callsite Message Size

```
---------------------------------------------------------------------------
@--- Callsite Message Sent statistics (all, sent bytes) -------------------
---------------------------------------------------------------------------
Name                 Site Rank    Count        Max       Mean        Min        Sum
Allgather              16    0        1          4          4          4          4
Allgather              16    1        1          4          4          4          4
Allgather              16    2        1          4          4          4          4
Allgather              16    3        1          4          4          4          4
Allgather              16    *        4          4          4          4         16

Allgatherv             22    0        1         28         28         28         28
Allgatherv             22    1        1         28         28         28         28
Allgatherv             22    2        1         28         28         28         28
Allgatherv             22    3        1         28         28         28         28
Allgatherv             22    *        4         28         28         28        112

Allreduce               2    0        3          8          8          8         24
Allreduce               2    1        3          8          8          8         24
Allreduce               2    2        3          8          8          8         24
Allreduce               2    3        3          8          8          8         24
Allreduce               2    *       12          8          8          8         96

...
```

Fine Tuning the Profile Run

mpiP Advanced Features

- User controlled stack trace depth
- Reduced output for large scale experiments
- Application control to limit scope
- Measurements for MPI I/O routines

Controlled by MPIP environment variable

- Set by user before profile run
- Command line style argument list
- Example: MPIP = “-c –o –k 4”

mpiP Parameters

Param.	Description	Default
-c	Concise Output / No callsite data	
-f dir	Set output directory	
-k n	Set callsite stack traceback size to n	1
-l	Use less memory for data collection	
-n	Do not truncate pathnames	
-o	Disable profiling at startup	
-s n	Set hash table size	256
-t x	Print threshold	0.0
-v	Print concise & verbose output	

Controlling the Stack Trace

Callsites are determined using stack traces

- Starting from current call stack going backwards
- Useful to avoid MPI wrappers
- Helps to distinguishes library invocations

Tradeoff: stack trace depth

- Too short: can't distinguish invocations
- Too long: extra overhead / too many call sites

User can set stack trace depth

- -k <n> parameter

Concise Output

Output file contains many details

- Users often only interested in summary
- Per callsite/task data harms scalability

Option to provide concise output

- Same basic format
- Omit collection of per callsite/task data

User controls output format through parameters

- -c = concise output only
- -v = provide concise and full output files

Limiting Scope

By default, mpiP measures entire execution

- Any event between MPI_Init and MPI_Finalize

Optional: controlling mpiP from within the application

- Disable data collection at startup (-o)
- Enable using MPI_Pcontrol(x)
  - x=0: Disable profiling
  - x=1: Enable profiling
  - x=2: Reset profile data
  - x=3: Generate full report
  - x=4: Generate concise report

Limiting Scope / Example

```
for(i=1; i < 10; i++)
{ switch(i)
  {
    case 5:
      MPI_Pcontrol(2);
      MPI_Pcontrol(1);
      break;
    case 6:
      MPI_Pcontrol(0);
      MPI_Pcontrol(4);
      break;
    default:
      break; }
  /* ... compute and communicate for one timestep ... */
}
```

Reset & Start in Iteration 5

Stop & Report in Iteration 6

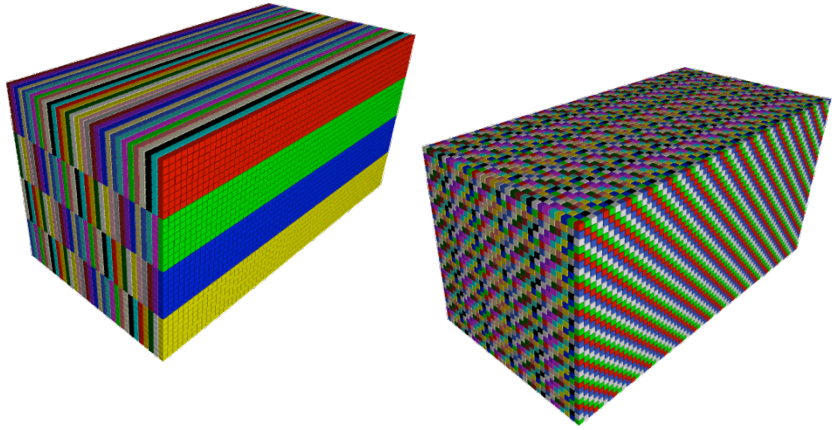
mpiP Case Study

First Principle Molecular Dynamics Code @ LLNL

- Tuning at 65.536 nodes on BG/L

Two main observations

- Few MPI_Bcasts dominate
  - ➢ Better node mappings
    - Up to 64% speedup



- Significant time spent in datatype operations
  - Hidden in underlying support libraries
  - ➢ Simplified data type management
    - 30% performance improvement

Platforms

Highly portable design

- Built on top of PMPI, which is part of any MPI
- Very few dependencies

Tested on many platforms, including

- Linux (x86, x86-64, IA-64, MIPS64)
- BG/L & BG/P
- AIX (Power 3/4/5)
- Cray XT3/4/5 with Catamount and CNL
- Cray X1E

mpiP Installation

Download from http://sourceforge.net/projects/mpip

- Current release version: 3.1.2
- CVS access to development version

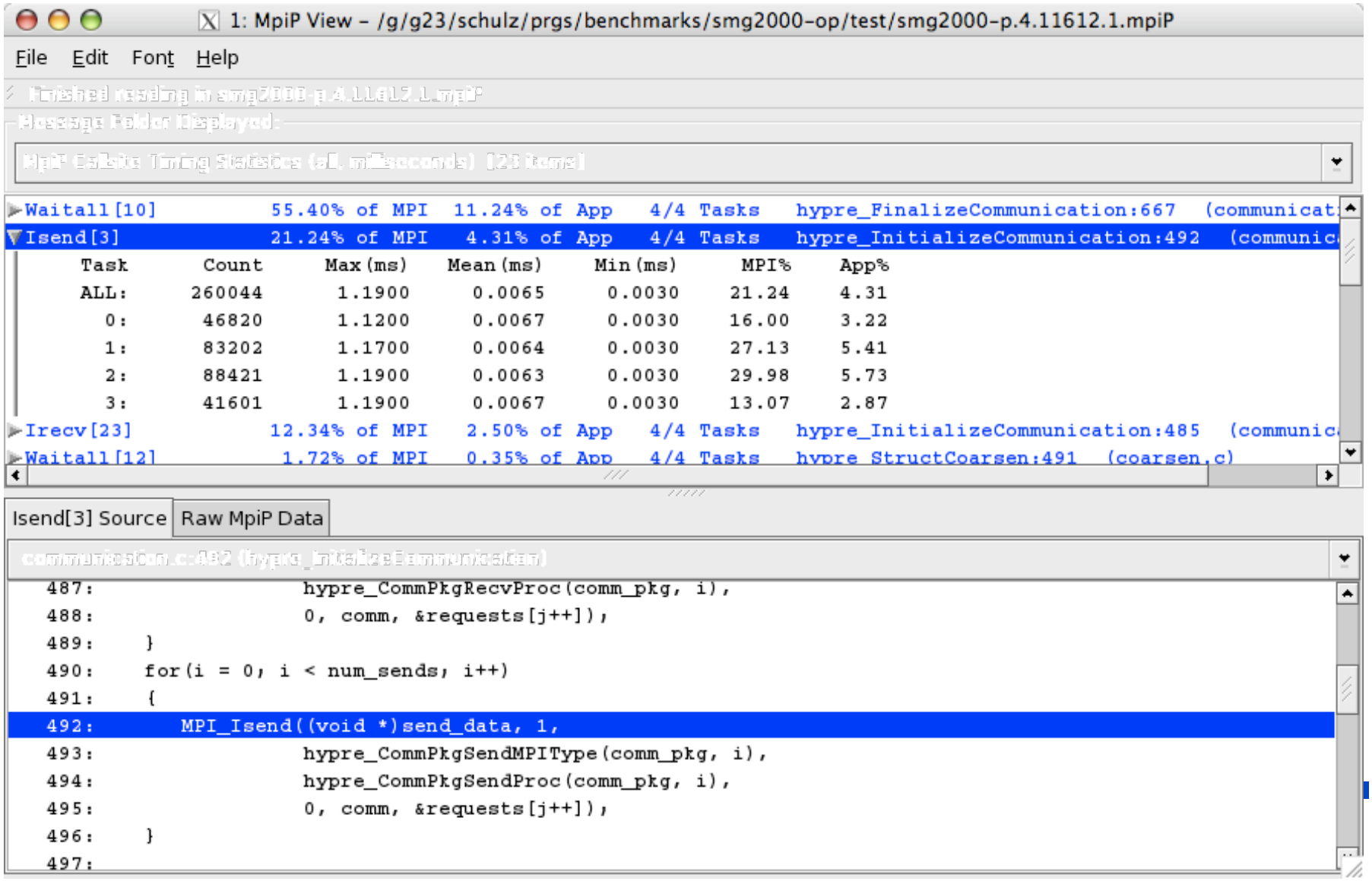
Autoconf-based build system with options to

- Disable I/O support
- Pick a timing option
- Choose name demangling scheme
- Build on top of the suitable stack tracer
- Set maximal stack trace depth

mpiPView: The GUI for mpiP

- Optional: displaying mpiP data in a GUI
- Implemented as part of the Tool Gear project
- Reads mpiP output file
- Provides connection to source files
- Usage process
- First: select input metrics
- Hierarchical view of all callsites
- Source panel once callsite is selected
- Ability to remap source directories

Example


1: MpiP View - /g/g23/schulz/prgs/benchmarks/smg2000-op/test/smg2000-p.4.11612.1.mpiP
File Edit Font Help
Waitall[10] 55.40% of MPI 11.24% of App 4/4 Tasks hypre_FinalizeCommunication:667 (communicat
Isend[3] 21.24% of MPI 4.31% of App 4/4 Tasks hypre_InitializeCommunication:492 (communic
Task Count Max(ms) Mean(ms) Min(ms) MPI% App%
ALL: 260044 1.1900 0.0065 0.0030 21.24 4.31
0: 46820 1.1200 0.0067 0.0030 16.00 3.22
1: 83202 1.1700 0.0064 0.0030 27.13 5.41
2: 88421 1.1900 0.0063 0.0030 29.98 5.73
3: 41601 1.1900 0.0067 0.0030 13.07 2.87
Irecv[23] 12.34% of MPI 2.50% of App 4/4 Tasks hypre_InitializeCommunication:485 (communic
Waitall[12] 1.72% of MPI 0.35% of App 4/4 Tasks hypre_StructCoarsen:491 (coarsen.c)
Isend[3] Source
Raw MpiP Data
487: hypre_CommPkgRecvProc(comm_pkg, i),
488: 0, comm, &requests[j++]);
489: }
490: for(i = 0; i < num_sends; i++)
491: {
492: MPI_Isend((void *)send_data, 1,
493: hypre_CommPkgSendMPIType(comm_pkg, i),
494: hypre_CommPkgSendProc(comm_pkg, i),
495: 0, comm, &requests[j++]);
496: }
497: