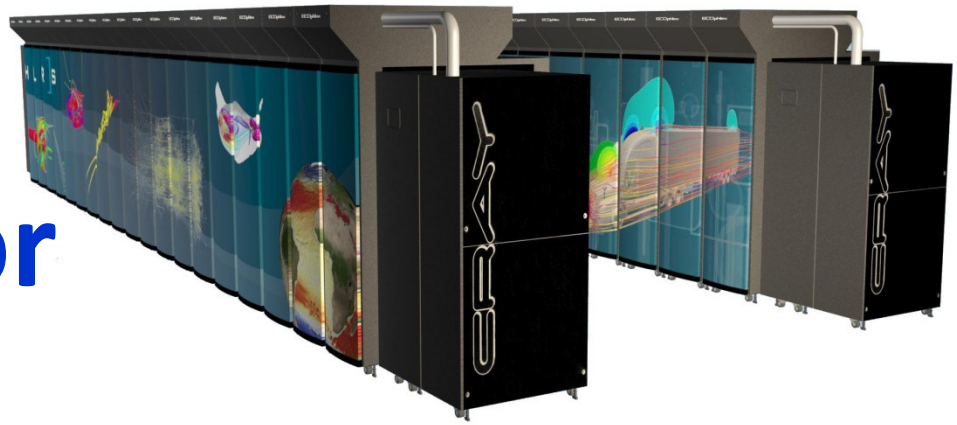

Methodology for Optimizing an application for MPPs

Jason J Beech-Brandt
Cray UK

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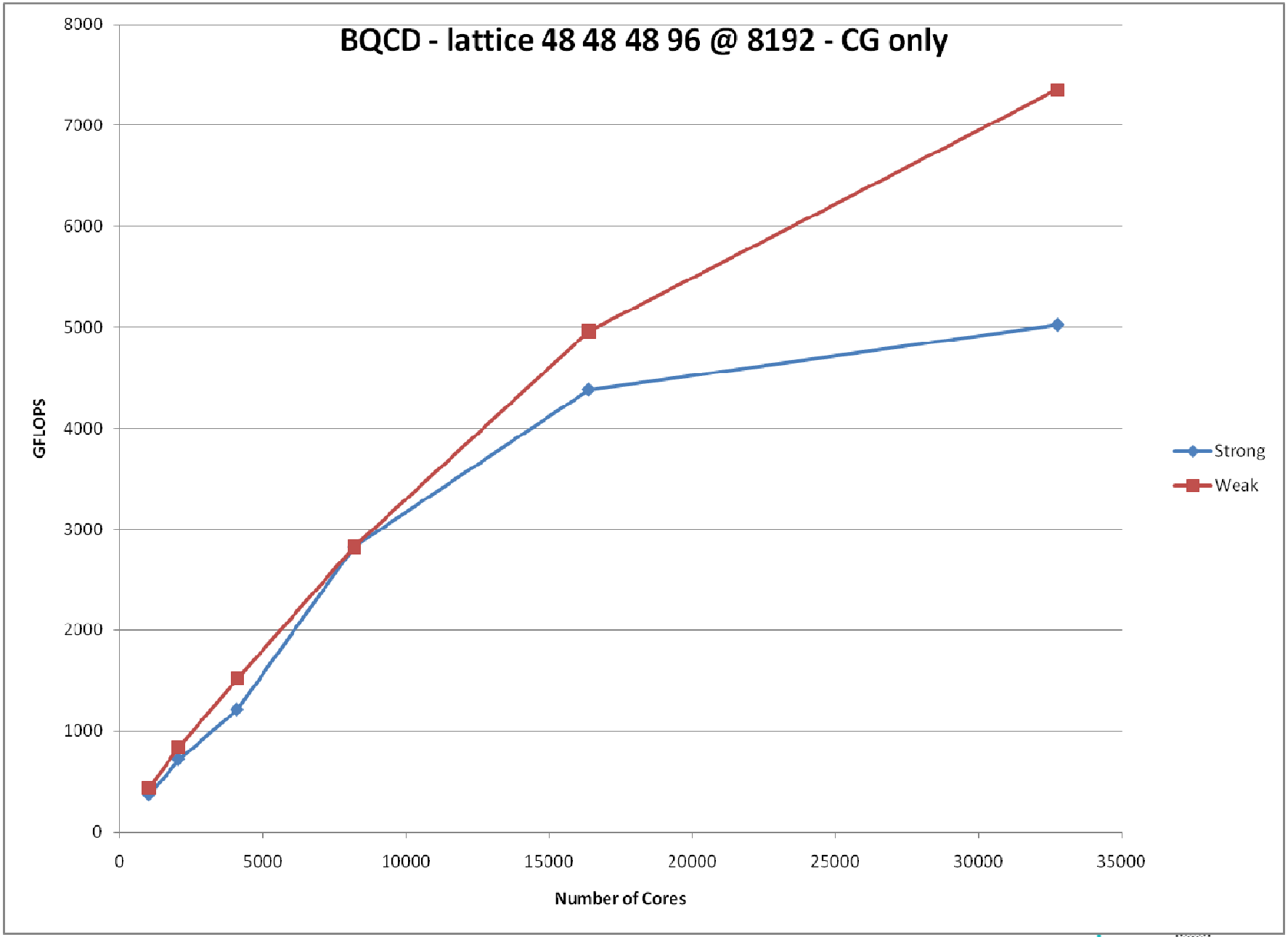
The steps – 1) Identify Application and Science Worthy Problem

- Formulate the problem
  - The problem identified should make good science sense
    - No publicity stunts that are not of interest
  - It should be a production style problem
    - Weak scaling
      - Finer grid as processors increase
      - Fixed amount of work when processors increase
    - Strong scaling
      - Fixed problem size as processors increase
        - Less and less work for each processor as processors increase



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The steps – 2) Instrument the application

- Instrument the application
  - Run the production case
    - Run long enough that the initialization does not use > 1% of the time
    - Run with normal I/O
  - Use Craypat's APA
    - First gather sampling for line number profile
    - Second gather instrumentation (-g mpi,io)
      - Hardware counters
      - MPI message passing information
      - I/O information

load module
make
pat_build -O apa a.out
Execute
pat_report *.xf
pat_build –O *.apa
Execute

CRAYPAT AUTOMATIC PERFORMANCE ANALYSIS A(APA)

Using Craypat MPI statistics

```
MPI Msg Bytes |  MPI Msg |   MsgSz | 16B<= |  256B<= |   4KB<= |Experiment=1
              |    Count |    <16B | MsgSz |   MsgSz |   MsgSz |Function
              |          |   Count | <256B |    <4KB |   <64KB | Caller
              |          |         | Count |   Count |   Count |  PE[mmm]
 3062457144.0 | 144952.0 | 15022.0 |  39.0 | 64522.0 | 65369.0 |Total
|-------------------------------------------------------------------------
| 3059984152.0 | 129926.0 |      -- |  36.0 | 64522.0 | 65368.0 |mpi_isend_
||------------------------------------------------------------------------
|| 1727628971.0 |  63645.1 |      -- |   4.0 | 31817.1 | 31824.0 |MPP_DO_UPDATE_R8_3DV.in.MPP_DOMAINS_MOD
3|              |          |         |       |         |         | MPP_UPDATE_DOMAIN2D_R8_3DV.in.MPP_DOMAINS_MOD
||||-----------------------------------------------------------------------
4||| 1680716892.0 |  61909.4 |      -- |    -- | 30949.4 | 30960.0 |DYN_CORE.in.DYN_CORE_MOD
5|||              |          |         |       |         |         | FV_DYNAMICS.in.FV_DYNAMICS_MOD
6|||              |          |         |       |         |         |  ATMOSPHERE.in.ATMOSPHERE_MOD
7|||              |          |         |       |         |         |   MAIN__
8|||              |          |         |       |         |         |    main
|||||||||-----------------------------------------------------------------
9|||||||| 1680756480.0 |  61920.0 |      -- |    -- | 30960.0 | 30960.0 |pe.13666
9|||||||| 1680756480.0 |  61920.0 |      -- |    -- | 30960.0 | 30960.0 |pe.8949
9|||||||| 1651777920.0 |  54180.0 |      -- |    -- | 23220.0 | 30960.0 |pe.12549
|||||||||=================================================================
```

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Memory allocation data from Craypat

```
Table 7:  Heap Leaks during Main Program

 Tracked | Tracked | Tracked |Experiment=1
  MBytes |  MBytes | Objects |Caller
     Not |     Not |     Not | PE[mmm]
 Freed % |   Freed |   Freed |

  100.0% | 593.479 |   43673 |Total
|-----------------------------------------
|   97.7% | 579.580 |   43493 |_F90_ALLOCATE
||----------------------------------------
||   61.4% | 364.394 |     106 |SET_DOMAIN2D.in.MPP_DOMAINS_MOD
3|         |         |         | MPP_DEFINE_DOMAINS2D.in.MPP_DOMAINS_MOD
4|         |         |         |  MPP_DEFINE_MOSAIC.in.MPP_DOMAINS_MOD
5|         |         |         |   DOMAIN_DECOMP.in.FV_MP_MOD
6|         |         |         |    RUN_SETUP.in.FV_CONTROL_MOD
7|         |         |         |     FV_INIT.in.FV_CONTROL_MOD
8|         |         |         |      ATMOSPHERE_INIT.in.ATMOSPHERE_MOD
9|         |         |         |       ATMOS_MODEL_INIT.in.ATMOS_MODEL
10         |         |         |        MAIN__
11         |         |         |         main
||||||||||-----------------------------
12|||||||||    0.0% | 364.395 |     110 |pe.43
12|||||||||    0.0% | 364.394 |     107 |pe.8181
12|||||||||    0.0% | 364.391 |      88 |pe.1047
```

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H L R S

Craypat load-imbalance data

Table 1: Profile by Function Group and Function

Time %	Time	Imb. Time	Imb. Time %	Calls	Experiment=1 Group Function PE='HIDE'
100.0%	1061.141647	--	--	3454195.8	Total
70.7%	750.564025	--	--	280169.0	MPI_SYNC
45.3%	480.828018	163.575446	25.4%	14653.0	mpi_barrier_(sync)
18.4%	195.548030	33.071062	14.5%	257546.0	mpi_allreduce_(sync)
7.0%	74.187977	5.261545	6.6%	7970.0	mpi_bcast_(sync)
15.2%	161.166842	--	--	3174022.8	MPI
10.1%	106.808182	8.237162	7.2%	257546.0	mpi_allreduce_
3.2%	33.841961	342.085777	91.0%	755495.8	mpi_waitall_
14.1%	149.410781	--	--	4.0	USER
14.0%	148.048597	446.124165	75.1%	1.0	main

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Hardware Counters

```
USER / MPP_DO_UPDATE_R8_3DV.in.MPP_DOMAINS_MOD
------------------------------------------------------------------------
  Time%                                              10.2%
  Time                                           49.386043 secs
  Imb.Time                                        1.359548 secs
  Imb.Time%                                           2.7%
  Calls                        167.1 /sec            8176.0 calls
  PAPI_L1_DCM                10.512M/sec         514376509 misses
  PAPI_TLB_DM                 2.104M/sec         102970863 misses
  PAPI_L1_DCA               155.710M/sec        7619492785 refs
  PAPI_FP_OPS                                           0 ops
  User time (approx)          48.934 secs      112547914072 cycles  99.1%Time
  Average Time per Call                           0.006040 sec
  CrayPat Overhead : Time      0.0%
  HW FP Ops / User time                                 0 ops  0.0%peak(DP)
  HW FP Ops / WCT
  Computational intensity      0.00 ops/cycle         0.00 ops/ref
  MFLOPS (aggregate)           0.00M/sec
  TLB utilization             74.00 refs/miss       0.145 avg uses
  D1 cache hit,miss ratios    93.2% hits             6.8% misses
  D1 cache utilization (M)    14.81 refs/miss       1.852 avg uses
```

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The steps – 3) Examine Results

- Examine Results
  - Is there load imbalance?
    - Yes – fix it first – go to step 4
    - No – you are lucky
  - Is computation > 50% of the runtime
    - Yes – go to step 5
  - Is communication > 50% of the runtime
    - Yes – go to step 6
  - Is I/O > 50% of the runtime
    - Yes – go to step 7

The steps – 4) Application is load imbalanced

- What is causing the load imbalance
  - Computation
    - Is decomposition appropriate?
    - Would RANK_REORDER help?
  - Communication
    - Is decomposition appropriate?
    - Would RANK_REORDER help?
    - Are receives pre-posted
- OpenMP may help
  - Able to spread workload with less overhead
    - Large amount of work to go from all-MPI to Hybrid
      - Must accept challenge to OpenMP-ize large amount of code
- Go back to step 2
    - Re-gather statistics

Need Craypat reports

Is SYNC time due to computation?

Craypat load-imbalance data

Table 1: Profile by Function Group and Function

Time %	Time	Imb. Time	Imb. Time %	Calls	Experiment=1 Group Function PE='HIDE'
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14.1%	149.410781	--	--	4.0	USER
14.0%	148.048597	446.124165	75.1%	1.0	main

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The steps – 5) Computation is Major Bottleneck

- What is causing the Bottleneck?
  - Computation
    - Is application Vectorized
      - No – vectorize it
    - What library routines are being used?
  - Memory Bandwidth
    - What is cache utilization?
    - TLB problems?
- OpenMP may help
  - Able to spread workload with less overhead
    - Large amount of work to go from all-MPI to Hybrid
      - Must accept challenge to OpenMPize large amount of code
- Go back to step 2
    - Re-gather statistics
- Session 5 – Optimization II

Need Hardware counters
&
Compiler listing in hand

The steps – 6) Communication is Major Bottleneck

- What is causing the Bottleneck?
  - Collectives
    - MPI_ALLTOALL
    - MPI_ALLREDUCE
    - MPI_REDUCE
    - MPI_GATHERV/MPI_SCATTERV
  - Point to Point
    - Are receives pre-posted
      - Don't use MPI_SENDRECV
    - What are the message sizes
      - Small – Combine
      - Large – divide and overlap
- Session 8 – Optimization V
- OpenMP may help
  - Able to spread workload with less overhead
    - Large amount of work to go from all-MPI to Hybrid
      - Must accept challenge to OpenMP-ize large amount of code

Look at craypat report
MPI message sizes

The steps – 7) I/O is Major Bottleneck

- What type of I/O?
  - One writer – large files
    - Stripe across most OSTs
  - All writers – small files
    - Stripe across one OST
  - MPI-I/O?
    - Try using subset of writers
  - Go back to step 2
    - Re-gather statistics
- Session 7 – Optimization IV

Look at craypat report on
file statistics
Look at read/write sizes


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Thank You!