Binary Instrumentation Support for Measuring Performance in OpenMP Programs

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SSCA2 (GraphAnalysis.org)

```
double findSubGraphs(graph* G,
        edge* maxIntWtList, int maxIntWtListSize)
{
...
#pragma omp parallel
{
#pragma omp barrier
...
#pragma omp for
   for (vert=start[phase_num];
        vert<start[phase_num+1]; vert++) {
...
      int myLock = omp_test_lock(&vLock[w]);
      if (myLock) {
...
```

OpenMP Tools

- Making common tools for OpenMP is hard
  - Source level standard does not include monitoring standard
  - E.g., MPI has the PMPI interception standard
- Commercial compilers have their own private OpenMP tools
- Opari2 is the only active open tool
  - Uses source translation techniques

Source Translation is Tricky!

- Harder to fit into a development toolchain
- Source code in real applications can get very complicated!
- Modern programming languages are not toy LALR(1) grammars!
- Tool effort can bog down in managing source instrumentation issues
- Commercial compiler OpenMP tools use binary instrumentation

Example: Intel Threading Tools

“Binary Instrumention for Intel Thread Profiler works better with the OpenMP* Compatibilty Libraries (dynamic version: libiomp5.so or libguide40.so) available via an Intel Compiler. This library has been instrumented for Intel Thread Profiler with the User-Level Synchronization API's. This library is used by default with the Intel Compiler, and can be used with an OpenMP* GCC* compiled application. If a 3rd party OpenMP* library is used, Thread Profiler can still collect data, but Intel Thread Profiler will not comprehend the OpenMP calls - it will be analyzed as a POSIX* application.”

http://software.intel.com/en-us/articles/how-to-analyze-linux-applications-with-the-intel-thread-profiler-for-windows

Example: IBM's OpenMP

“DPOMP is developed based on IBM’s dynamic instrumentation infrastructure (DPCL). This supports binary instrumentation of FORTRAN, C and C++ programs. The DPOMP Tool was developed for dynamic instrumentation of OpenMP applications. It inserts into the application binary calls to a POMP (Performance Monitoring Interface for OpenMP) compliant library. The DPOMP tool reads the binary of the application, as well as the binary of a POMP compliant library and instruments the binary of the application with calls defined in the POMP compliant library. DPOMP requires DPCL version 3.2.6.”

http://www.research.ibm.com/actc/projects/dynaperf2.shtml

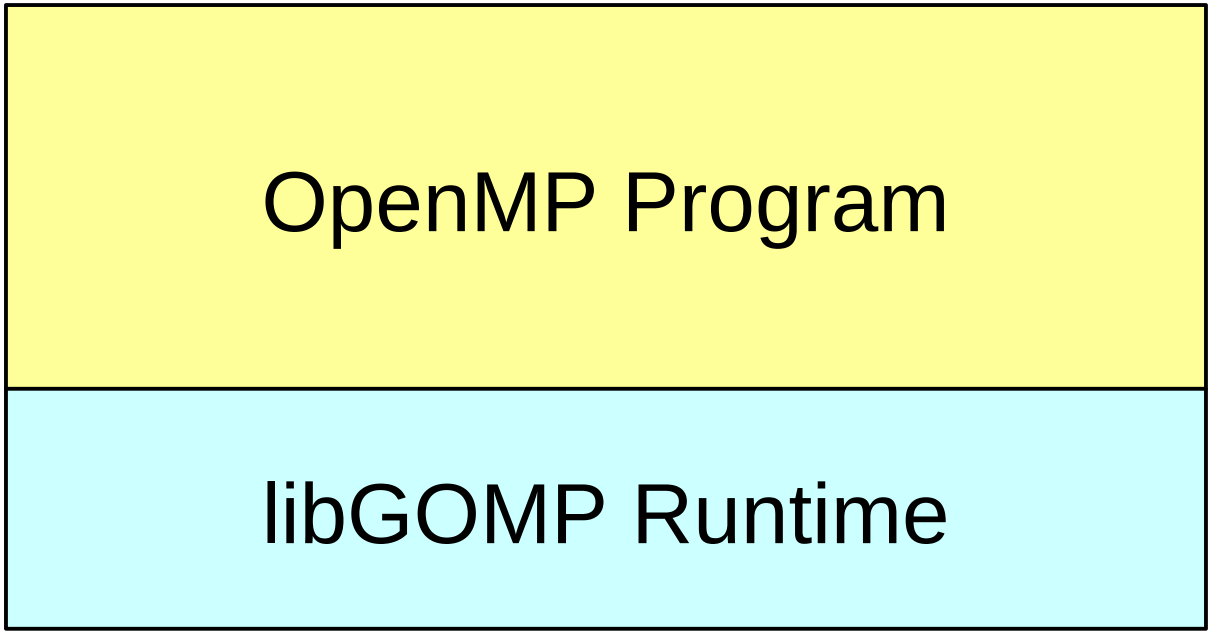
Example: BG/P Help Page

“The POMP OpenMP Performance Monitoring Interface is a proposed API for enabling programmers and performance tools to obtain information about the performance of OpenMP constructs in an OpenMP program.

The IBM compilers and HPCT toolkit provide a prototype implementation of some of the POMP functionality. The full POMP API provides a number of events to report the time spent in different parts of compiler-instrumented user code, and the prototype POMP implementation provides a core subset of the events, sufficient to instrument most OpenMP programs. The current POMP implementation allows profiling of Parallel Regions, WorkShare Do and Parallel Do Loops.”

https://www.alcf.anl.gov/user-guides/bgp-pomp

Gnu OpenMP



OpenMP Parallel Section

```
int main()
{
   …
   #pragma omp parallel …
   { … }
   …
}
```

```
8048714: call 8048570 <GOMP_parallel_start@plt
8048719: lea  0x14(%esp),%eax
804871D: mov  %eax,(%esp)
8048720: call 8048796 <main._omp_fn.0>
8048725: call 8048590 <GOMP_parallel_end@plt>
```

OpenMP Parallel For

```
#pragma omp parallel ...
{
   #pragma omp for ...
   for (i=0; I < 100000; ++i)
   { ... }
}
```

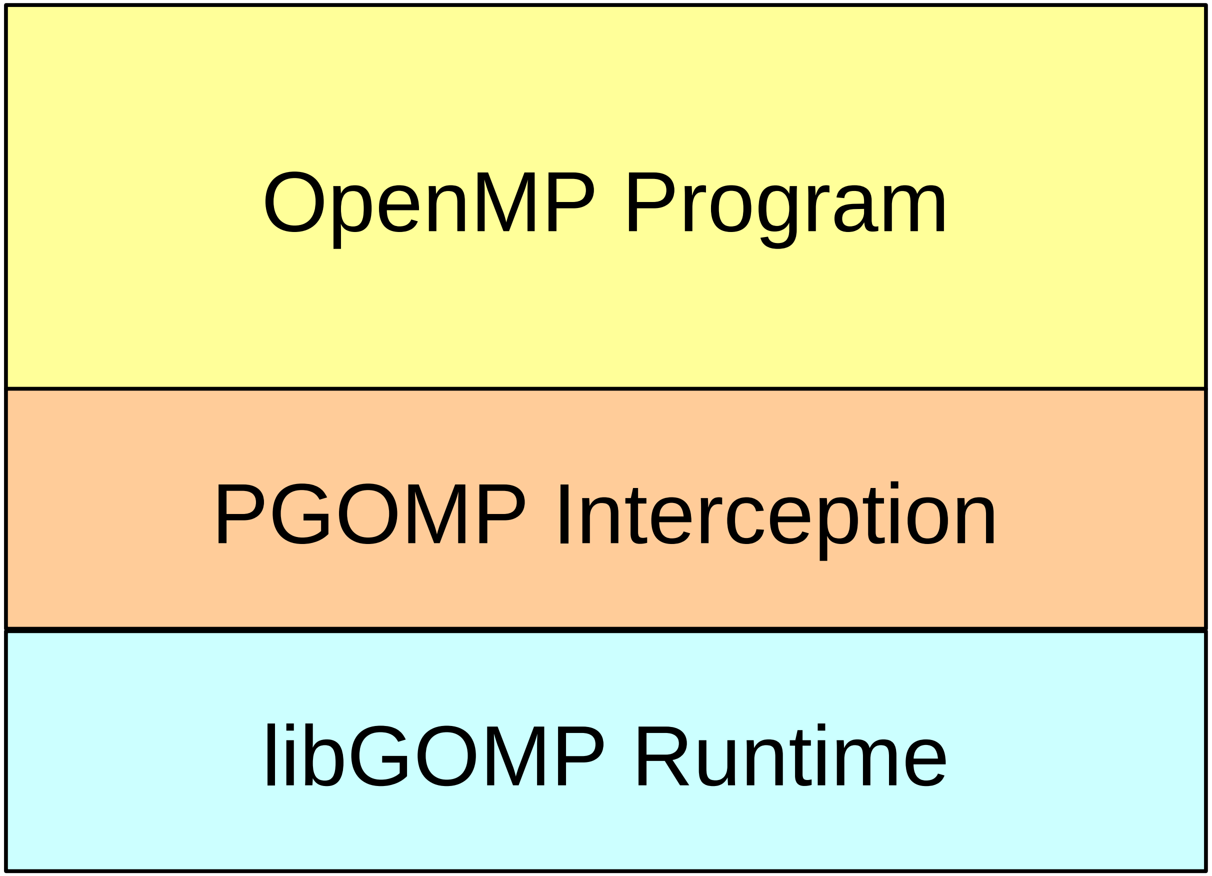
```
...
80487Fd: cmp    %edx,-0x10(%ebp)
8048800: jl     80487f5 <main._omp_fn.0+0x5f>
8048802: call   8048580 <GOMP_barrier@plt>
```

OpenMP Critical Section

```
#pragma omp parallel ...
{
   #pragma omp critical
   { ... }
}
```

```
 ...
8048807: call 8048620 <GOMP_critical_start@plt
 ...
8048855: call 80485b0 <GOMP_critical_end@plt>
```

PGOMP Profiling Interception



Functions Intercepted by PGOMP

```
GOMP_parallel_start
GOMP_parallel_end
GOMP_barrier
GOMP_critical_start
GOMP_critical_end
GOMP_critical_name_start
GOMP_critical_name_end
GOMP_single_start
```

```
omp_init_lock
omp_destroy_lock
omp_set_lock
omp_test_lock
omp_unset_lock
omp_set_nest_lock
omp_test_nest_lock
omp_unset_nest_lock
```

PGOMP Trace Mode

Name Return-address ThreadID EnterTime ExitTime

```
...
GOMP_barrier 0x8049875 0 0.030259 0.030260
GOMP_parallel_end 0x8049ab8 0 0.030265 0.030268
GOMP_parallel_start 0x804a5b6 0 0.030320 0.030399
GOMP_barrier 0x804a1a6 3 0.030400 0.030408
GOMP_barrier 0x804a1a6 0 0.030407 0.030408
GOMP_barrier 0x804a1a6 2 0.030399 0.030408
GOMP_barrier 0x804a1a6 1 0.030399 0.030408
...
omp_set_lock 0x804a28b 3 0.030492 0.030492
omp_unset_lock 0x804a2ab 3 0.030497 0.030497
```

PGOMP Aggregation Mode

Name	StartAddress	EndAddress	ThreadID	WaitTime	ExecutionTime	Count
GOMP_parallel_start	0x804bee4	0x804bef1	0	0.000	0.199738	1
omp_test_lock	0x804b92e	0x804b983	2	0.00000	0.035917	82350
omp_set_lock	0x804bd94	0x804bdbb	0	0.013750	0.012610	29629
omp_set_lock	0x804bd94	0x804bdbb	1	0.013258	0.012036	28090
omp_set_lock	0x804bd94	0x804bdbb	2	0.012979	0.011716	27149
omp_set_lock	0x804bd94	0x804bdbb	3	0.010780	0.009787	23017
GOMP_barrier	0x804bdfb	0x804bdfb	3	0.018024	0.000000	1631
GOMP_barrier	0x804bdfb	0x804bdfb	2	0.010153	0.000000	1631
GOMP_barrier	0x804bdfb	0x804bdfb	1	0.010693	0.000000	1631
GOMP_barrier	0x804bdfb	0x804bdfb	0	0.008843	0.000000	1631

Performance?

```
> ./plain-ssca2.sh |& grep Time
Time taken for Scalable Data Gen. is  0.033507 sec.
Time taken for Kernel 1 is  0.001707 sec.
Time taken for Kernel 2 is  0.000193 sec.
Time taken for Kernel 3 is  0.000530 sec.
Time taken for Kernel 4 is  0.208041 sec.

> ./pgomp-aggregate.sh |& grep Time
Time taken for Scalable Data Gen. is  0.029894 sec.
Time taken for Kernel 1 is  0.003377 sec.  (20x)
Time taken for Kernel 2 is  0.008760 sec.  (45x)
Time taken for Kernel 3 is  0.010045 sec.  (19x)
Time taken for Kernel 4 is  2.725435 sec.  (13x)

Trace output is MUCH slower...
```

Location issues

Optimized code from SSCA2:

```
...
8049186: call   80488c0 <GOMP_barrier@plt>
80491C4: jmp    80488c0 <GOMP_barrier@plt>
80491D0: call   80488c0 <GOMP_barrier@plt>
...
```

Optimized code from our own test program:

```
804880E: call 8048660 <GOMP_critical_start@plt
8048860: jmp  80485e0 <GOMP_critical_end@plt>
```

Conclusion

- PGOMP == easy instrumentation of Gnu-compiled OpenMP programs
- Initial prototype results are promising
- Much work still to do
  - Support OTF (Open Trace Format)
  - Support other tool's data formats (HPCToolkit)
  - Support POMP I/F? PAPI? Others?
  - Provide useful data processing scripts
    - At least some address->code mapping

www.cs.nmsu.edu/please/projects/pgomp
www.cs.nmsu.edu/~jcook

prosportstickers.com

"Any questions?"