OpenMP

Threading on Blue Gene Q

T. Hater

JSC

February 5, 2013

Motivation

- BG/Q CPU: 16 cores with 4-way SMT: 64 threads total.
- Two instruction pipelines per core.

⇒ Need to issue two instructions per cycle and core.

Outline

1. Very fast intro to OpenMP.
2. How to use it on BG/Q.
3. Things to watch out for.

OpenMP fast forward

What is OpenMP?

- Platform independent threading standard.
- Support by most major compilers.
- Relies on programmer annotations with pragmas.
- Additional runtime functions.

Parallel regions

- Basic threading

```
!$omp parallel
    ... executed n times ...
!$omp end parallel
```

- Forks `OMP_NUM_THREADS` threads and joins them.

⇒ Implicit barrier at the end.

- OpenMP constructs appear inside `parallel`.

Simple loops

- Parallelize a counting loop

```
!$omp parallel do
   do i = 1,N
      ...
   end do
!$omp end parallel do
```

- Every thread is assigned a chunk of the iterations.
- May specify scheduling `schedule({static|dynamic|guided}[, chunk_size])`.

⇒ `runtime` leaves it to OpenMP.

- `collapse` merges nested loops.

Access specifiers

- `parallel` construct may include access attributes for variables

```
!$omp parallel clause(var,...)
    ...
!$omp end parallel
```

- Where `clause` is one of `{shared|private|firstprivate}`.
- Special: `reduction(var:op,...)`.
- Set the default: `default({shared|none})`

Synchronization

- Only a single thread at a time.

```
!$omp critical
    ... one at a time ...
!$omp end critical
```

- Only a single (the master) thread.

```
!$omp {master|single}
      ... once ...
!$omp end {master|single}
```

- Atomic operations.

```
!$omp atomic
```

- Wait for all threads.

```
!$omp barrier
```

Sections

```
!$omp sections
!$omp section
    ... one thread ...
!$omp end section
...
!$omp section
    ... another thread ...
!$omp end section
!$omp end sections
```

- Does not scale!

Tasks

- Create a task

```
!$omp task
      ... concurrently ...
!$omp end task
```

- One task per encountering thread
- Synchronizing tasks

```
!$omp taskwait
```

⇒ Only for **direct** descendants.

OpenMP on Blue Gene Q

Compiling for OpenMP

- Using the XL compilers.
- Add `-qsmp=omp` to compiler and linker flags.
- Automatically enables `-O2 -qhot`.

⇒ Suppress with `-qsmp=omp:noopt`.

- XLF can try to automatically parallelize loops.

⇒ Enable on top of OpenMP with `-qsmp`.

XL OpenMP

- OMP_NUM_THREADS = OMP_THREAD_LIMIT = $\frac{64}{RanksPerNode}$
- May oversubscribe, but be careful.
- OMP_PROC_BIND = True (fixed) due to CNK limitation.
- No conforming nested OpenMP.
- Utilize thread local storage with !IBM* THREADLOCAL.

Exploiting BG/Q features

- XL OpenMP runtime already uses some BG/Q features.
- `omp barrier` and `lock` use L2 atomic hardware support.
- `omp atomic` exploits hardware atomic support.
- Waiting threads go to sleep.

Tuning for performance

General ideas

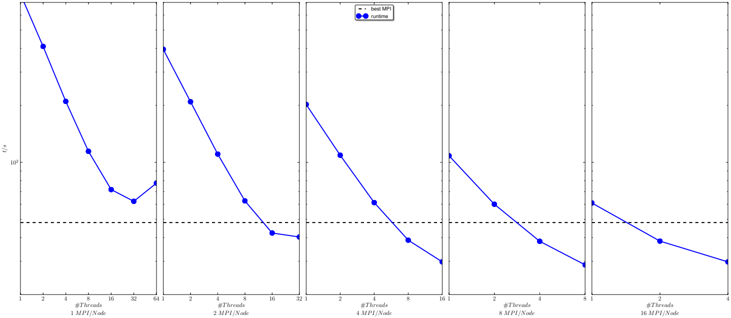
- Try threaded libraries.
- Combine multiple constructs into one region.
- Cut down on synchronization.
- Consider `nowait`.
- Avoid `flush`.

Overhead

- Rule of thumb: $100\mu s$ for tasks, $10\mu s$ for loops and $1\mu s$ else.
  - `{lock|barrier|critical}` $\leq 1\mu s$
  - `parallel` $1\mu s$ (1 thread) – $50\mu s$ (64 threads)
  - do loops $1\mu s$ (1 thread) – $50\mu s$ (64 threads)
  - Task `create/wait` $2\mu s$ (1 thread) – $50\mu s$ (16 threads)
- Scheduling: prefer `runtime` and `static`.

Mixing OpenMP and MPI

- Good starting point: 16 MPI processes + 4 OpenMP threads
- Issues
  - Global parallelization vs hotspots
  - Explicit communication vs shared memory issues
  - Memory usage



Resources

- XL compiler manuals
  `http://pic.dhe.ibm.com/infocenter/compbg/v121v141/`
- OpenMP standard
  `http://www.openmp.org/mp-documents/OpenMP3.1.pdf`
- OpenMP overview card
  - `http://openmp.org/mp-documents/OpenMP3.1-CCard.pdf`
  - `http://openmp.org/mp-documents/OpenMP3.1-FortranCard.pdf`

Questions?

MPI Comm threads

- If unused threads are available, BG/Q can use them to asynchronously make progress on MPI requests.
- To use, initialize MPI with `MPI_Init_thread` and `MPI_THREAD_MULTIPLE`.
- The rest should happen automagically.

⇒ Not tested.

Tuning worksharing

- Control the runtime via environment variable `XLSMPOPTS="key=val :..."`
- Basic: specify defaults for OpenMP attributes
- Advanced: Tune work sharing
  - `yields[=num]`, `spins[=num]` and `delays[=num]`.
  - Algorithm for dynamic worksharing.
    1. Scan for work `spins` times, if nothing, idle for `delays`.
    2. Scan again, if still nothing yield to another thread.
    3. Repeat `yields` times, then go to sleep.
  - Set `spins=yields=0` to force pure busy waiting.
- Set `BG_SMP_FAST_WAKEUP=YES`.

⇒ Might be useful, but I found no gain.

⇒ Be wary of deadlocks if oversubscribing.