First Experiences with Intel Cluster OpenMP

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Overview

- Systems used
  - EM64T (dual Nocona) with Gbit Ethernet and Infiniband, Debian 3.1 (Sarge)
  - Itanium2 (HP zx6000) with Gbit Ethernet, SLES9pl3
  - Opteron would be a nice exercise, but CLOMP doesn't work on AMD…
- Basic numbers: Triad tests
- Application: Lattice-Boltzmann code
  - influence of algorithmic details
  - data layout considerations
- Odds and ends

General Remarks

- CLOMP == "extreme" ccNUMA
  - very long latencies, expensive non-local access
  - page replications can lead to memory problems
  - but: placement is handled "automatically"
- Consequence: A well-optimized, ccNUMA-aware OMP code that scales well on Altix does not necessarily scale well with CLOMP
  - example: boundary code must be optimized for local access
- Good stability on all systems with latest CLOMP release
- No problems and good performance with IP over IB
  - native IB not working yet

General Remarks

- Problems (RRZE-specific?)
  - memory footprint is about 2.5 times larger than expected from serial code (270MB instead of 61MB for vector triad)
    - Partially resolved by Intel (Jim C.)
  - huge core dumps even with small sharable heap and resident memory (2.4GB core with 200MB code)
  - Reproducible hangs on entry to parallel region when OMP_NUM_THREADS smaller than number of hosts in hostfile (only for LBMKernel)

Parallel Triad A(:)=B(:)+C(:)*D(:)

- Three flavors
  1. Standard triad, OMP parallel

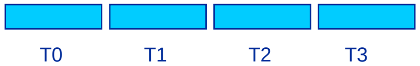

```
#pragma omp parallel for
   for(i=0; i<N; i++)
      a[i]=b[i]+c[i]*d[i];
```

  2. Throughput triad (separate local arrays on each thread)

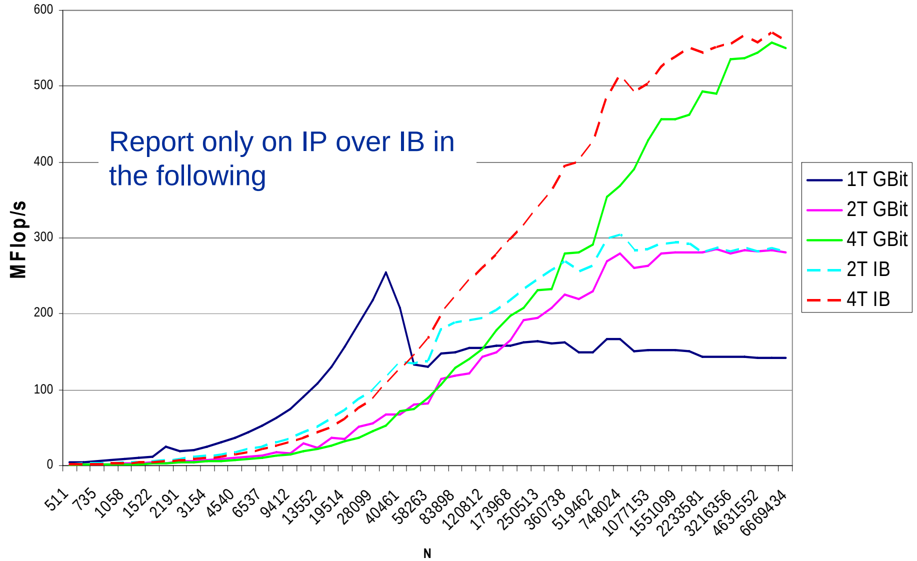
```
#pragma omp parallel
   sub_triad(N);
```

  3. Padded triad

```
#pragma omp parallel
   do_triad(N[myID],
     start[myID],a,b,c,d)
```



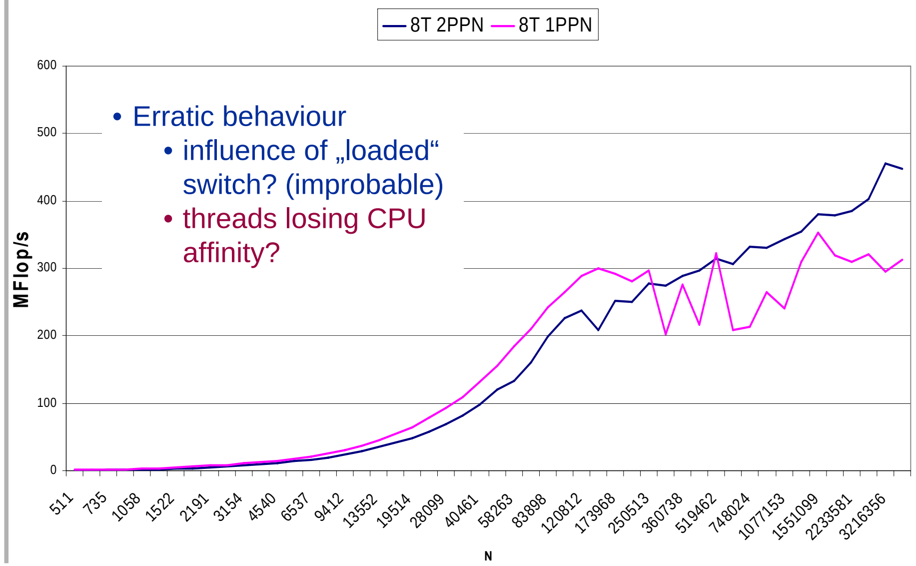
Standard Triad on GBit Ethernet vs. IP over IB (1T/node)



Filled vs. Half-filled nodes

- 2 ways to „fill the node“
  1. Keep unique names in hostfile and use 2 „real“ OpenMP threads per node with `--process_threads=2`
  2. Duplicate names in hostfile and use `--process_threads=1`
- Observations
  - breakdown of performance compared to the half-filled case for large N
  - Improvement with OpenMP for medium-sized arrays
  - `--process_threads=2`: quite erratic performance data
- Breakdown was actually expected (the same happens on single node with pure OpenMP)
- Erratic behaviour
  - influence of „loaded“ switch? (improbable)
  - Threads losing CPU affinity?

Threads vs. processes on node

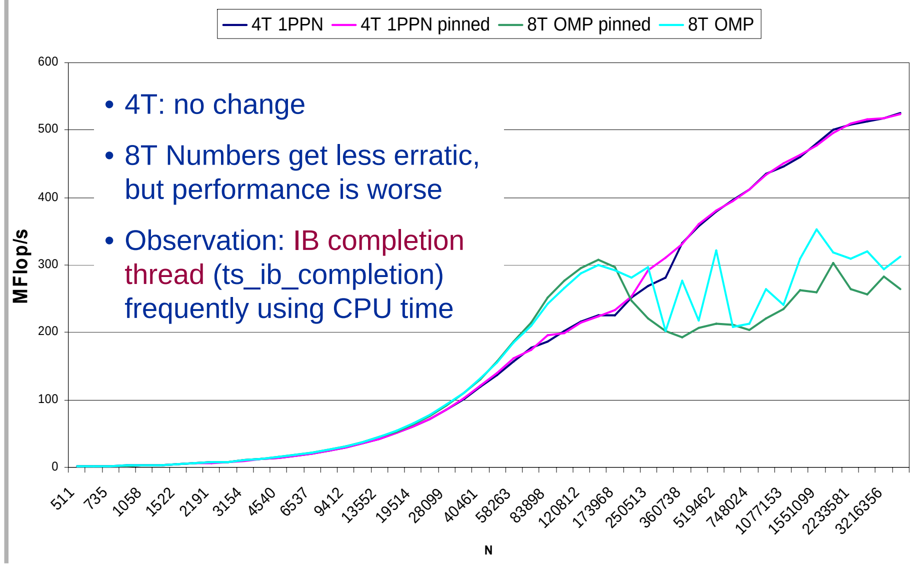


Pinning of threads

- Performance results seem quite erratic when using all available CPUs on a node
- Possible remedy? → pin threads to CPUs
  - using PLPA for portability reasons

```
#pragma omp parallel
{
#pragma omp critical
{
    if(PLPA_NAME(api_probe)()!=PLPA_PROBE_OK) {
      cerr << "PLPA failed!" << endl;
  } else {
    plpa_cpu_set_t msk;
    PLPA_CPU_ZERO(&msk);
    PLPA_CPU_SET(omp_get_thread_num() & 1,&msk);
    PLPA_NAME(sched_setaffinity)((pid_t)0, (size_t)32, &msk);
  }
}
}
```


Results for pinned triad (4 and 8 threads)



- 4T: no change
- 8T Numbers get less erratic, but performance is worse
- Observation: IB completion thread (ts_ib_completion) frequently using CPU time

Lattice Boltzmann Method

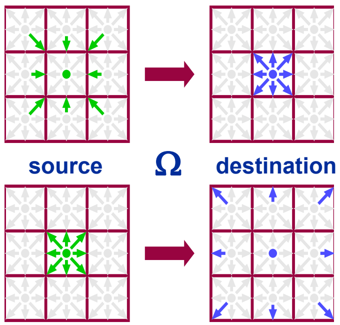
- Numerical Method for Simulation of Fluids

Stream-Collide (Pull-Method)

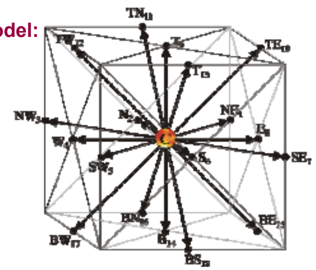
Get the distributions from the neighboring cells in the source array and store the relaxed values to one cell in the destination array

Collide-Stream (Push-Method)

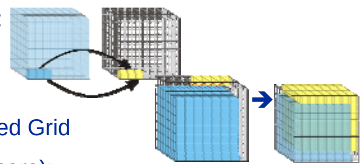
Take the distributions from one cell in the source array and store the relaxed values to the neighboring cells in the destination array



D3Q19 model:



Two Grids:



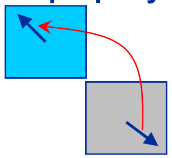
Compressed Grid (not used here):

LBMKernel – Code Structure for Collide-Stream Step

```
double precision f(0:xMax+1,0:yMax+1,0:zMax+1,0:18,0:1)
!$OMP PARALLEL DO
do z=1,zMax
   do y=1,yMax
      do x=1,xMax
          if( fluidcell(x,y,z) ) then
             LOAD f(x,y,z, 0:18,t)
             ...Relaxation (complex computations)...
             SAVE f(x  ,y  ,z  , 0,t+1)
             SAVE f(x+1,y+1,z  , 1,t+1)
             SAVE f(x  ,y+1,z  , 2,t+1)
             SAVE f(x-1,y+1,z  , 3,t+1)
             …
             SAVE f(x  ,y-1,z-1,18,t+1)
          endif
      enddo
   enddo
enddo
```

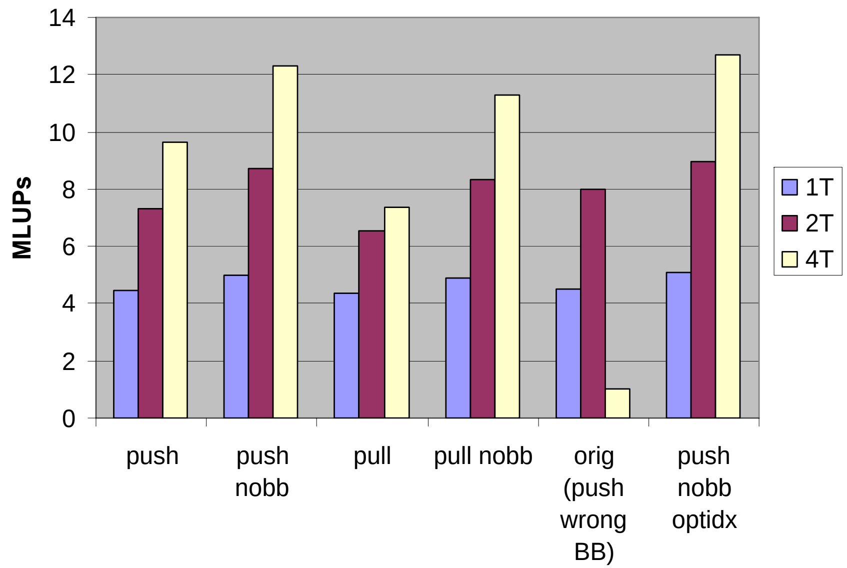
LBMKernel

- Scalability beyond 2 nodes was very bad with standard code
- proper choice of geometry (long thin channel) can restore scalability
  - not a general solution
- Solution: bounceback (boundary) routine was not properly optimized for local access
  - on ccNUMA, this is a negligible effect for small obstacle density (n^2)
  - on CLOMP, it is devastating



- Still: indexing has significant impact on performance
  - "push" vs. "pull" algorithm
  - parallelized dimension should be the outermost one to minimize false sharing: (i,j,v,t,k) better than (I,j,k,v,t)
- Might profit from ghost layers, but is this still OpenMP???

Influence of Bounceback and push vs. Pull for 128x64x128 and (i,j,k,v,t) layout



DMRG

- Large C++ code, OpenMP parallelized
  - good scalability not really expected, but a good example for porting
  - cache-bound, so not optimized for ccNUMA
- Important issues:
  - use `new (kmp_sharable)` for dynamic objects used in parallel regions
  - derive classes from `kmp_sharable_base` if dynamic objects are used in parallel regions
- Possible problem with global objects (still under investigation)

Conclusions

- Cluster OpenMP is an intersting programming experience
- Imagine a ccNUMA machine with automatic page migration (wow!) and an awfully slow network
- If something strange happens (performancewise), use profiler by all means
  - Otherwise (with OMP) negligible boundary effects may become dominant with CLOMP
- With CLOMP, performance results tend to be more scattered than usual
- Looking forward to AMD-enabled versions…