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Overview

- Setting the Scene
- The Time Scale
- Is OpenMP easy?
- How about NUMA, clusters, memory hierarchies?
- Does OpenMP scale?
- Summary

Setting the scene

- **My perspective:**
  HPC support in a technical university
  (engineering, natural sciences …)

- **4 … 144-way compute servers**
  1000s jobs per day
  8-16 processors per job on the average

- **MPI - OpenMP – Autoparallel – Hybrid**

The Time Scale

today **OpenMP running on all big SMPs:**
Cray X, Fujitsu Primepower, HP Superdome, IBM Regatta, NEC SX, SGI Altix, Sun Fire => **OpenMP is expensive**

2003 **dual processors Intel boxes with hyperthreading**
for 4 threads, not scalable, but cheap

2004 **4-way Opteron machines attractive (NUMA!!)**

2005 **16-way Opteron boxes at a very competitive price**
with many OpenMP compilers on Lin/Win/Sol available

2006 **dual core processors everywhere (incl. laptops)**

2007 **low latency networks are getting commodity**
OpenMP on Infiniband-Clusters

2008 **4-8-core processors**
=> 8-32 – way systems affordable

2009 **OpenMP V3.0 available for the end user**

Are we keeping pace?

Is OpenMP easy?

- Yes, you can easily run into data races.
- We need data race detection / prevention tools in the development cycle.
- The default shared strategy for global data may be inadequate

```
!$OMP DEFAULT(SHARED|PRIVATE|NONE)
!$OMP THREADSHARED(list)
!$OMP THREADPRIVATE(list)
```

  need for a compiler switch? (Fujitsu: frt –Kprivate …)

- autoscoping = cooperating with the compiler

```
!$OMP PARALLEL DEFAULT(AUTO)
```

Automatic Scoping – Sometimes it would really help!

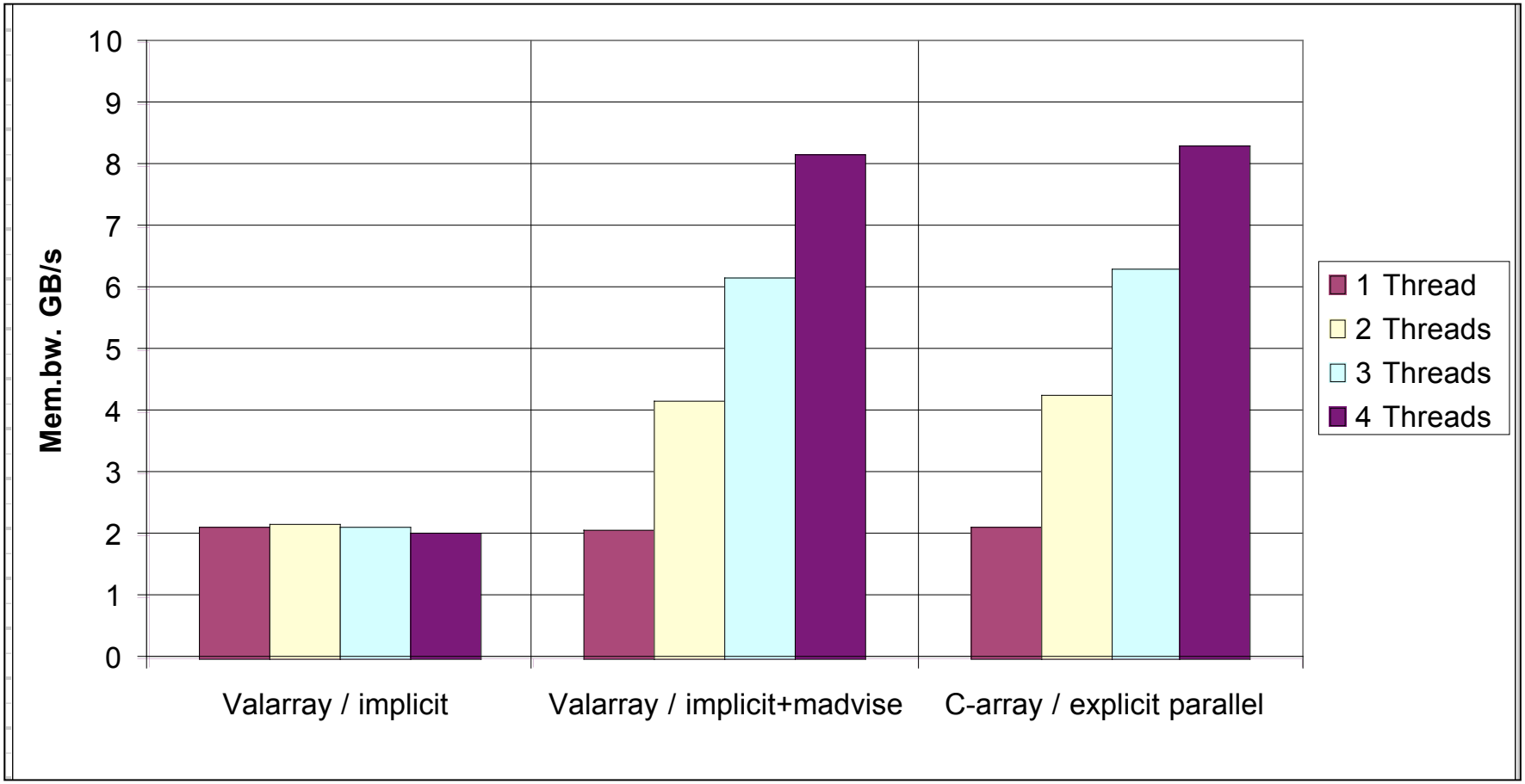
```
...
!$omp & omegaz,prode,qdens,qjc,qmqc,redbme,redbpe,renbme, &
!$omp & renbpe,resbme,resbpe,reubme,reubpe,rkdbmk,rkdbpk,rknbmk, &
!$omp & rknbpk,rksbmk,rksbpk,rkubmk,rkubpk,rtdbme,rtdbpe,rtnbme, &
!$omp & rtnbpe,rtsbme,rtsbpe,rtubme,rtubpe,rudbme,rudbmx,rudbmy, &
!$omp & rudbmz,rudbpe,rudbpx,rudbpy,rudbpz,runbme,runbmx,runbmy, &
!$omp & runbmz,runbpe,runbpx,runbpy,runbpz,rusbme,rusbmx,rusbmy, &
!$omp & rusbmz,rusbpe,rusbpx,rusbpy,rusbpz,ruubme,ruubmx,ruubmy, &
!$omp & ruubmz,ruubpe,ruubpx,ruubpy,ruubpz,rvdbme,rvdbmx,rvdbmy, &
!$omp & rvdbmz,rvdbpe,rvdbpx,rvdbpy,rvdbpz,rvnbme,rvnbmx,rvnbmy, &
!$omp & rvnbmz,rvnbpe,rvnbpx,rvnbpy,rvnbpz,rvsbme,rvsbmx,rvsbmy, &
!$omp & rvsbmz,rvsbpe,rvsbpx,rvsbpy,rvsbpz,rvubme,rvubmx,rvubmy, &
!$omp & rvubmz,rvubpe,rvubpx,rvubpy,rvubpz,rwdbme,rwdbmx,rwdbmy, &
!$omp & rwdbmz,rwdbpe,rwdbpx,rwdbpy,rwdbpz,rwnbme,rwnbmx,rwnbmy, &
!$omp & rwnbmz,rwnbpe,rwnbpx,rwnbpy,rwnbpz,rwsbme,rwsbmx,rwsbmy, &
!$omp & rwsbmz,rwsbpe,rwsbpx,rwsbpy,rwsbpz,rwubme,rwubmx,rwubmy, &
!$omp & rwubmz,rwubpe,rwubpx,rwubpy,rwubpz,tc,tdb,tdbm, &
!$omp & tdbp,teb,tkc,tkdb,tkdbm,tkdbp,tkeb,tknb, &
!$omp & tknbm,tknbp,tksb,tksbm,tksbp,tkub,tkubm,tkubp, &
!$omp & tkwb,tnb,tnbm,tnbp,tsb,tsbm,tsbp,tub, &
!$omp & tubm,tubp,twb,uc,udb,udbm,udbp,ueb, &
!$omp & unb,unbm,unbp,usb,usbm,usbp,uub,uubm, &
!$omp & uubp,uwb,vc,vdb,vdbm,vdbp,veb,velosq, &
!$omp & vnb,vnbm
!$omp & vubp,vwb
!$omp & wnbm,wnb
!$omp & wwb,xiax                                                    &
!$omp & xiazeb,x                                                    nb, &
!$omp & xibzsb,x                                                    ub)
  do i = is,ie
     ---- 1600 lines omitted ----
  end do
```

```
!$omp parallel default(__auto) do
do i = is,ie
     ---- 1600 lines omitted ----
  end do
```

How about NUMA, clusters, memory hierarchies?

- **Frequently first-touch is not the way to go!**
  If data is initialized by the master process (e.g. by reading from files), data needs to be migrated (automatically or manually)
- **!$OMP NEXTTOUCH(*|*var_list*)**
  is easy to understand, nothing breaks, if it is not supported
  => we'll have to wait for the migration
- **How about**
  !$OMP PREFETCH(*var_list*, [*urgency*])
  Stef Salvini, EWOMP 2003
  http://www.rz.rwth-aachen.de/ewomp03/omptalks/Tuesday/Session8/ewomp_salvini.mpg

NEXTTOUCH works



Stream saxpying in C/C++ on a 4-way Opteron system running Solaris

Does OpenMP scale well?

- Well, occasionally … rarely
- How are we going to use all these nice 8..32-way boxes in the near future?
- Parallelizing while loops
  The proposal is on the table since the very beginning:
  #pragma omp taskq
  (KAI guidec/guidec++, Intel icc)
- Better support of nested parallelism.
  Can we efficiently use OpenMP encapsulated in libraries?

```
User code calling a
    Library function(e.g. Newton alg.) calling
        User function
```

OpenMP Nested - orientation

```
!$OMP PARALLEL (name)
omp_get_thread_num(name)

level = omp_get_parallel_level()
omp_get_thread_num(level)

! Get thread id of ancestors
      do level = 0, omp_get_parallel_level()
            print *, omp_get_thread_num(level)
      end do
```

OpenMP Nested - threadprivate

- The **threadprivate** directive specifies that named global-lifetime objects are replicated, with each thread having its own copy.
- There needs to be a way to suppress additional copying in a lower level of nested parallelism.

```
SUBROUTINE SUB()
     COMMON /T/ A(1000000000)
     !$OMP THREADPRIVATE(/T/)
     !$OMP PARALLEL COPYIN(/T/)
        ...
        !$OMP PARALLEL WORKSHARE SHARED(/T/)
           A = ...
        !$OMP END PARALLEL WORKSHARE
        ...
     !$OMP END PARALLEL
  END SUBROUTINE SUB
```

Summary

- We need to hurry …
- Data race detection / prevention tools
- Autoscoping
- Task queues
- Nexttouch / prefetch
- Better nested support
  - Orientation
  - threadprivate