OpenMP - Cluster Extensions

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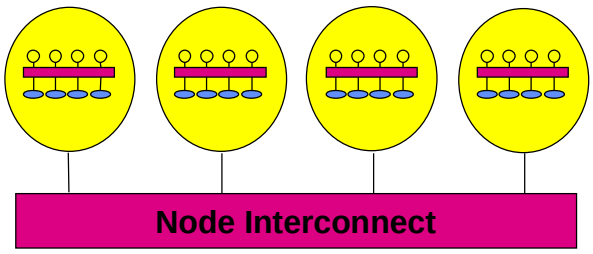
SMP - Cluster (Hybrid System)

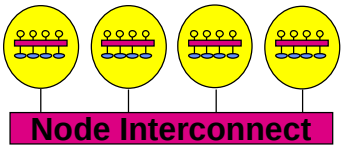
- Most modern high-performance computing (HPC) systems are clusters of SMP nodes



- DMP (distributed memory parallelization) on the node inteconnect
- SMP (symmetric multi-processing) inside of each node

SMP - Clusters Current Solutions for Programming

- MPI based:
  - the MPP model
    - **massively parallel processing**
    - **each CPU = one MPI process**
  - MPI + OpenMP
    - **each SMP node = one MPI process**
    - **MPI communication on the node interconnect**
    - **OpenMP inside of each SMP node**
    - **DMP with MPI & SMP with OpenMP**
  - MPI + automatic parallelization
- Other models:
  - HPF, MLP, ...
- **What about an OpenMP-like approach ?**

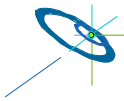


MPI + OpenMP on SMP-Clusters

- Advantages
  - Could be effective utilizing heavyweight communications between nodes and lightweight threads within a node
  - Less communication packets and uses larger communication packets than pure MPI on SMP Clusters.
- Disadvantages
  - Very Difficult to start with OpenMP & modify for MPI (non-incremental)
  - Very difficult to program, debug, modify and maintain
  - Generally, cannot do MPI calls from within parallel regions
  - Only people very experienced in both should use this mixed programming model - an intimidating programming model
  - Single Node AND single CPU performance suffers
- Could provide highest performance (at a cost!)

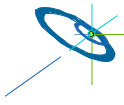
“Distributed OpenMP” Current Approaches

- New directives for distributing data
  - Portland Group (following slides)
  - Compaq
- No extensions to OpenMP itself, but an new more intelligent run time environment
  - Real World Computing Partnership (RWCP) Japan
- KAI announced KAP/Pro Toolset Network Edition
  - presumably also DVSM approach but there is no further information
  - available far 2001



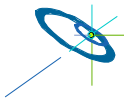
A New Parallel Programming Paradigm for SMP Clusters ?

- Ideally, a mixed parallel programming paradigm would exist that
  - enable parallelism using low level, efficient one-way communication between PEs
  - using an efficient multi-threaded mechanism between CPU within a PE
- Such a mixed parallel programming paradigm should
  - allow for full efficiency within an SMP System while also
  - retaining efficiency for distributed memory clusters
- Other desired features:
  - incremental parallelism
  - ease-of-programming
  - maintainability and debugability should be maintained



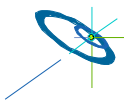
Distributed OMP

- A merging of SMP and cluster capabilities
  - Merge OpenMP + Craft + HPF technologies
  - Goal is to maintain full source compatibility with OpenMP
- A programmer should be able to
  - start with an OpenMP program and
  - later add mapping directives

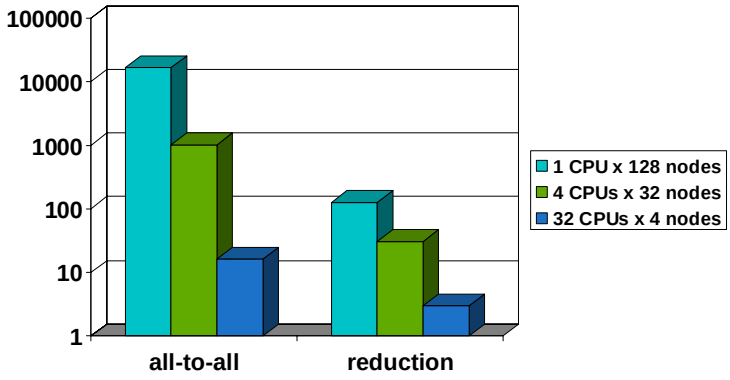


Distributed OMP - Characteristics

- Each node is treated as a single process with one-way communication between the nodes
- lightweight threads within a node
- Each node's program would utilize multiple threads according to OpenMP directives and OpenMP library calls
- Directives for data distribution to the nodes
  no explicit communication
- Less data movements between nodes plus larger packets of data.



Number of Communications



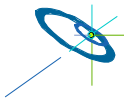
But the message size is increasing in the first case

Distributed OpenMP - Advantages

- One can have a single portable code that can be executed on SMP systems and distributed clusters and hybrid combinations of SMP clusters
- Single SMP node performance will not degrade
- Incremental parallelization capability
- Managers don’t have to risk “betting” on SMP systems being the dominant system

Distributed OpenMP - Disadvantages

- Not yet available (9-12 months)
- More complex than OpenMP or HPF
- User still must give some thought about data partitionment
- Performance tuning after mapping directives are added



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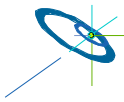
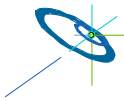


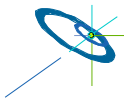
Compiler-Directed Software DSM

- CD-SDSM transparently executes OpenMP programs on Clusters of SMP's
- Compilation:
  - The particular compiler compiles the OpenMP C-program to a multi-threaded C-program with runtime library calls.
  - This program is compiled using a native C-compiler
  - linked with the libraries
- The executable is executed on each SMP node in a SPMD fashion (like MPI)



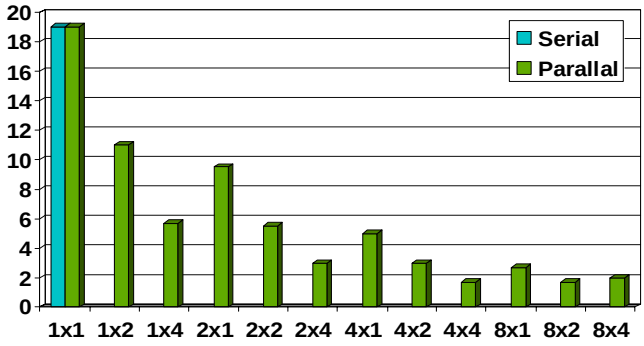
CD-SDSM Internals

- A part of the adress space of each process (running on a SMP node) is virtually shared between the nodes.
- Coherence of shared space is maintained by software
  - fine grain coherence control
  - compiler can optimize coherence operations (It knows about the source !!!)
  - these optimizations are crucial to obtain good performance
- Redundant barrier removal
  - Overhead for synchronization is large for SDSM



CD-SDSM Results

- Jacobi Overrelaxation Solver, Matrix4096x4096, 10 Its.



nodes x threads

Summary

- Distributed OpenMP
  - may provide an (excellent ?) technology path for SMP Clusters
  - Will be available in 9-12 months
  - Increased complexity
  - Not yet standardized
- CD-SDSM for OpenMP programs
  - available for C
  - shows promising results
  - easier for the programmer
- No experience for large configurations