Executing OpenMP Programs

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Presentation Outline

- Introduction to OpenMP
- Machine Architectures
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  - Distributed Memory
- MPI or OpenMP?
- OpenMP hello world program
- OpenMP on
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  - Itanium2 (Linux) Cluster
  - SGI Origin 2000 (IRIX) SMP
    - Environment Set-up
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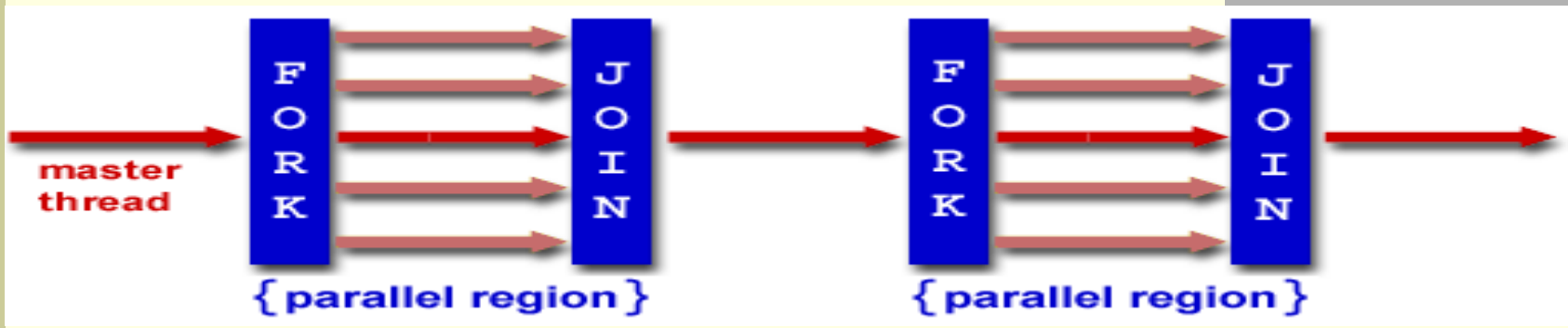
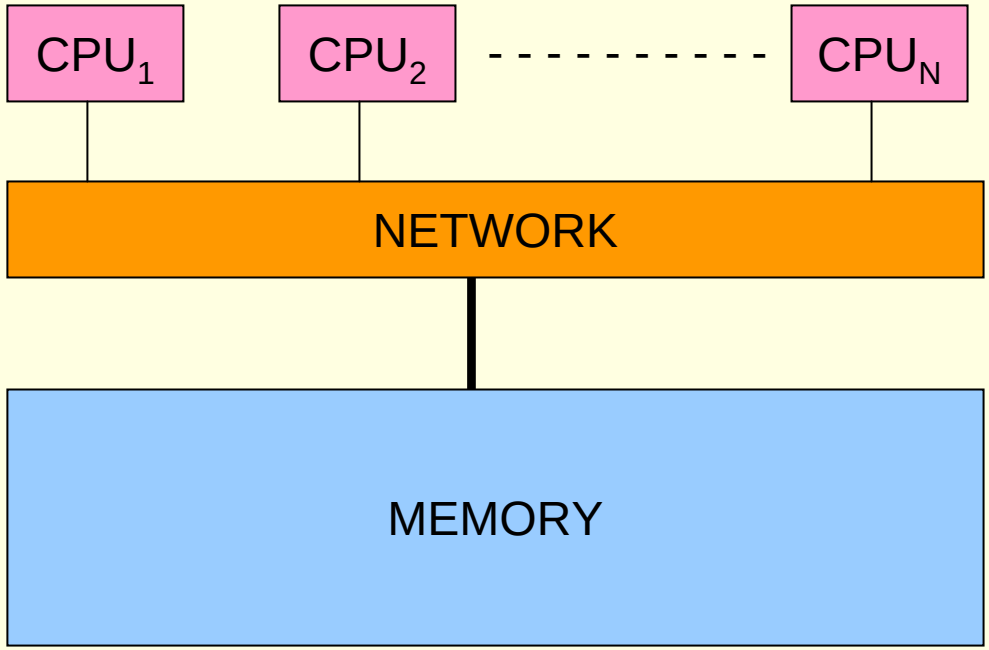
Introduction to OpenMP*



- Thread-based Parallelism
- Explicit Parallelism
- Fork-Join Model
- Compiler Directive Based
- Dynamic Threads

*Source: http://www.llnl.gov/computing/tutorials/openMP/#ProgrammingModel

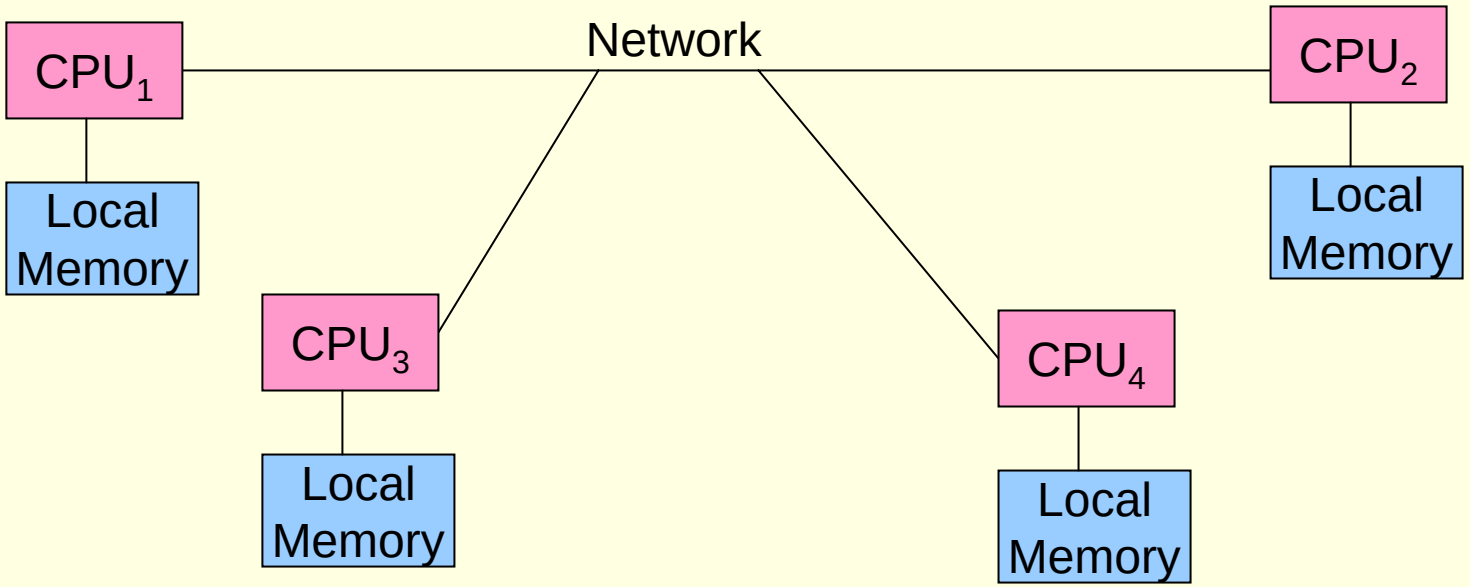
Machine Architectures
Shared Memory



FEATURES:
1) All CPUs share memory
2) CPUs access memory using the interconnection network

Example: Top Gun, Kirk, every node of the Itanium2 cluster is a dual-processor SMP machine

Machine Architectures
Distributed Memory



FEATURES:
1) Each node has its own local memory
2) Nodes share data by passing data over the network

Example: Sun Solaris Workstations

MPI or OpenMP?

- Recommended Use
  - MPI for Distributed Memory Machines
  - OpenMP for Shared Memory (SMP) Machines

- Hybrid MPI / OpenMP Use
  - Use MPI on clusters of SMP nodes to communicate among nodes, and use OpenMP to create multiple threads per SMP node
  - Example: Itanium2 Vampyre Cluster*

*Currently the Vampyre cluster does not have a supporting compiler for hybrid OpenMP and MPI programs.

OpenMP hello world program

Sample hello world OpenMP program:

```
#include <omp.h>

main ()  {
int nthreads, tid;

/* Fork a team of threads giving them their own copies of variables */
#pragma omp parallel private(tid)
  {
  /* Obtain and print thread id */
  tid = omp_get_thread_num();
  printf("Hello World from thread = %d\n", tid);

  /* Only master thread does this */
  if (tid == 0)
    {
    nthreads = omp_get_num_threads();
    printf("Number of threads = %d\n", nthreads);
    }
  }  /* All threads join master thread and terminate */
}
```

OpenMP on Top Gun

Top Gun is an IBM eServer pSeries 690 (p690) multiprocessor

System Summary	
Architecture	IBM POWER4
OS	AIX/LINUX
CPUs	16
Peak GFLOPS	83.2
Memory	32GB
Disk Storage	2TB

OpenMP on Top Gun Environment Set-up - 1

- Define the default number of threads in the environment variable OMP_NUM_THREADS

Example: for tcsh shell

```
%setenv OMP_NUM_THREADS 4
```

OpenMP on Top Gun Environment Set-up - 2

- The program can overwrite the default number of threads using the *omp_set_num_threads()* function.
- The maximum number of threads that can be created by this function is bounded by the environment variable OMP_NUM_THREADS.

  Example: Create two threads

  ```
  omp_set_num_threads(2);
  ```

OpenMP on Top Gun Program Compilation

- C Compiler: *xlc_r* with compile flag *-qsmp=omp*

  Usage:

  xlc_r –qsmp=omp [-o outfile] infile

  Example:

  %xlc_r –qsmp=omp -o hello helloworldOMP.c

- Other OpenMP compilers:
  - Fortran77: *xlf_r*
  - C++: *xlC_r*
- Complete list available at: http://research.utep.edu/Default.aspx?tabid=20687

OpenMP on Top Gun
Program Execution

- Execute the program like a normal program executable

  Example:

  % ./hello

  Hello World from thread = 3

  Hello World from thread = 0

  Number of threads = 4

  Hello World from thread = 1

  Hello World from thread = 2

OpenMP on Itanium2 Cluster

- Vampyre Cluster: 8-processor Intel Itanium2 Cluster, with dual (SMP) 900MHz Itanium2 processors per node
- Network Features: Externally accessible by 100 Mbps Ethernet; internal network runs at 1Gbps
- OS: Linux kernel 2.4.18-e.25
- OpenMP Compilers: Omni and Intel* Compilers

*Intel Compiler is available only for teaching purposes.

OpenMP on Itanium2 Cluster Environment Set-up

- Confirm that Omni and the Intel Compilers are visible in your path using the *which* command

  Example: for the Omni C compiler and Intel C Compiler

  ```
  % which omcc
  /usr/local/Omni/bin/omcc

  % which icc
  /usr/local/intel/cc/bin/icc
  ```

- Environment Variables: define OMP_NUM_THREADS

  Example: for tcsh shell

  ```
  % setenv OMP_NUM_THREADS 4
  ```

- Program can overwrite the default number of threads using the *omp_set_num_threads()* function

OpenMP on Itanium2 Cluster Program Compilation

- Omni C Compiler: *omcc*

  Usage:

  omcc [-o outfile] infile

  Example:

  % omcc –o hello1 helloworldOMP.c
- Intel C Compiler: *icc* with compile flag *-openmp*

  Usage:

  icc –openmp [-o outfile] infile

  Example:

  % icc –openmp –o hello2 helloworldOMP.c
- Other OpenMP Compilers:
  - Fortran: *omf77*
  - C++: *icc*

OpenMP on Itanium2 Cluster Program Execution

- Execute the program like a normal program executable

  Example: executing on node Sabina

  ```
  sabina > ./hello1
  Hello World from thread = 3
  Number of threads = 4
  Hello World from thread = 0
  Hello World from thread = 1
  Hello World from thread = 2
  ```

OpenMP on SGI Origin 2000

- Kirk: SGI Origin 2000 SMP machine with 8 180MHz MIPS R10000 processors
- 2.9 GB main memory, 32 KB L1 data cache, 32 KB L1 instruction cache and 1 MB unified L2 cache
- Operating System: IRIX64 Release 6.5
- Machine IP: kirk.sseal.cs.utep.edu

OpenMP on SGI Origin 2000 Environment Set-up

- Confirm that Omni Compilers are in your path using the *which* command

  Example:

  % which omcc

  /usr/local/Omni/bin/omcc

- Environment Variables: define OMP_NUM_THREADS

  Example: for tcsh shell

  % setenv OMP_NUM_THREADS 4

- Program can overwrite the default number of threads using the *omp_set_num_threads()* function

OpenMP on SGI Origin 2000 Program Compilation

- Omni C Compiler: *omcc*

  Usage:

  omcc [-o outfile] infile

  Example:

  % omcc –o hello helloworldOMP.c

OpenMP on SGI Origin 2000 Program Execution

- Execute the program like a normal program executable

  Example:

  ```
  % ./hello
  Hello World from thread = 1
  Hello World from thread = 3
  Hello World from thread = 0
  Hello World from thread = 2
  Number of threads = 4
  ```

Contacts and Websites

- System Administrators:
  - Jose Hernandez (jose@cs.utep.edu) for Top Gun
  - Leopoldo Hernandez (leo@cs.utep.edu) for Itanium2 Cluster (Vampyre) and SGI Origin 2000 (Kirk)
- System Web Sites:
  - Top Gun: http://research.utep.edu/topgun
  - Itanium2 Cluster: http://www.cs.utep.edu/~bdauriol/courses/ParallelAndConcurrentProgramming/vampyre.html
- OpenMP Links:
  - http://www.openmp.org
  - Omni OpenMP:http://phase.hpcc.jp/Omni/home.html
  - Tutorials:
    - http://www.llnl.gov/computing/tutorials/openMP/
    - http://www.msi.umn.edu/tutorial/scicomp/general/openMP/

Questions?