OpenMP®

SC'21 Booth Talk Series

NUMA in OpenMP - Home Sweet Home

Part I - What is NUMA?

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My background is in mathematics and physics

Previously, I worked at the University of Utrecht,
Convex Computer, SGI, and Sun Microsystems

Currently I work in the Oracle Linux Engineering organization

I have been involved with OpenMP since the introduction

I am passionate about performance and OpenMP in particular

What is NUMA?

NUMA

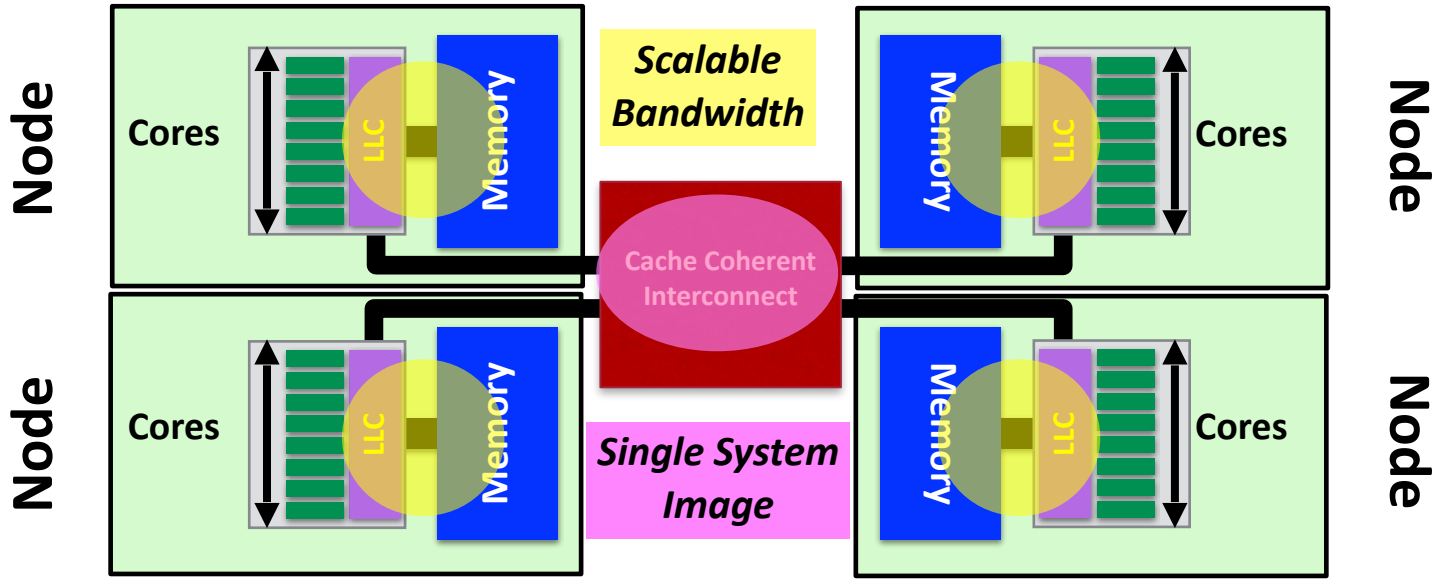
NUMA stands for Non-Uniform Memory Access

Simply said, this means that the time it takes to fetch data from memory is not a constant

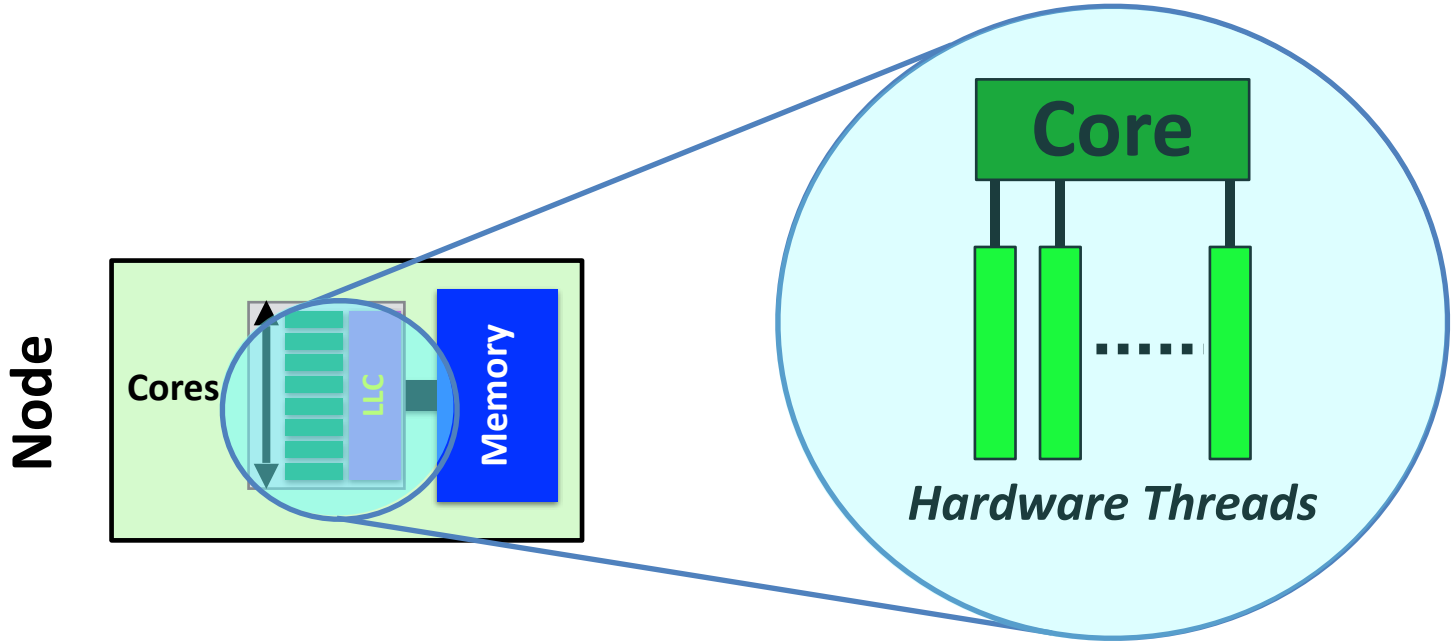
This time depends on where the data physically resides in memory

Let's look at a typical NUMA system

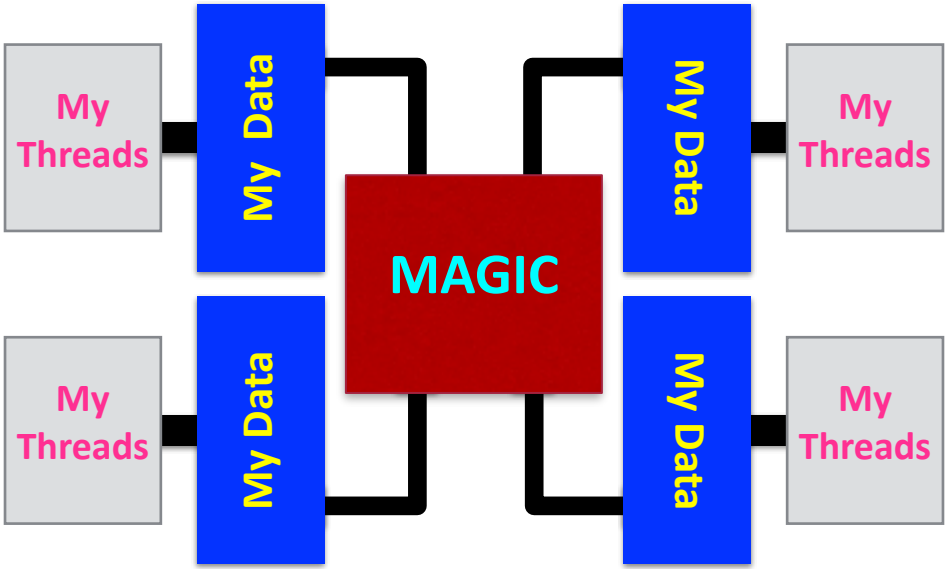
A Generic, but Contemporary NUMA System



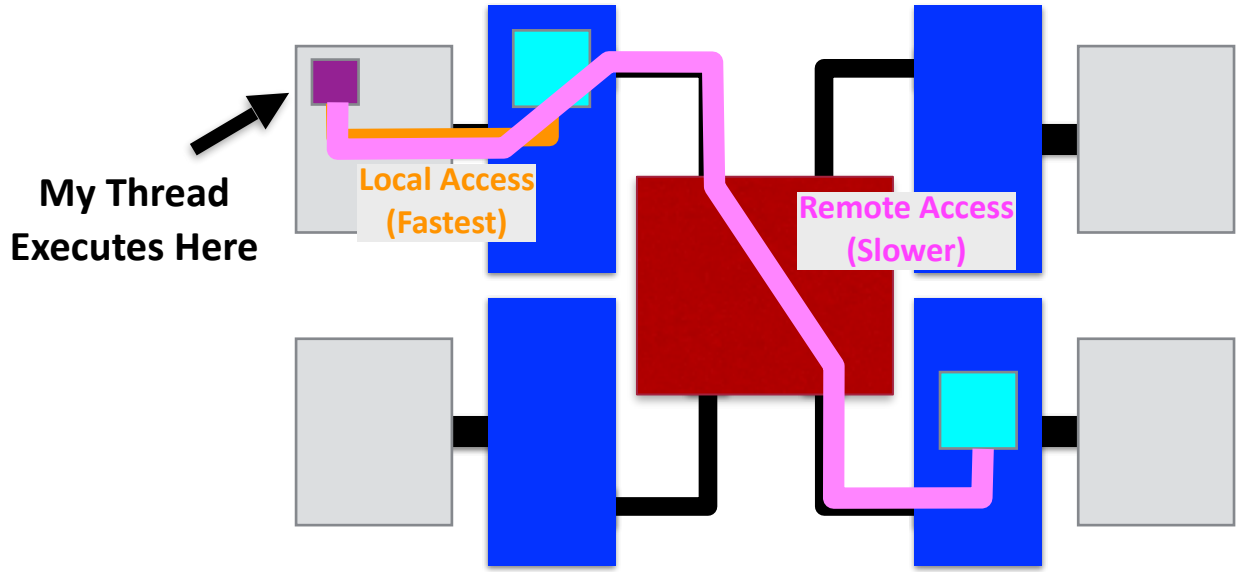
Hardware Threads



NUMA - The Developer's View

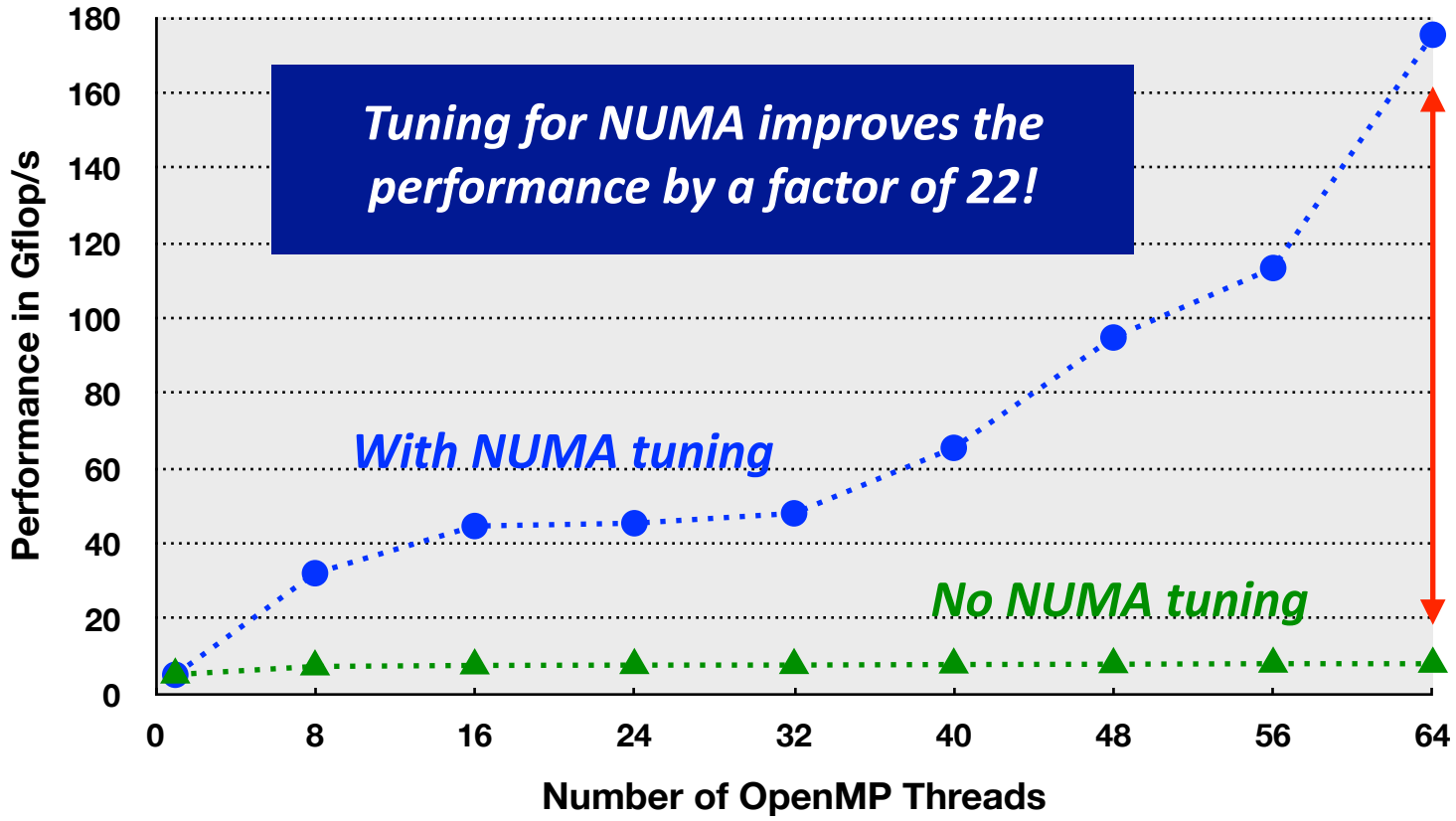


NUMA - Local versus Remote Access Times



Why NUMA Tuning Matters

Performance of a matrix-vector multiplication



Home Sweet Home

The Home Node

In a NUMA system, every memory page has a home node

The placement policy controls the location of the home node

A commonly used policy is called "First Touch"

The First Touch Placement Policy

The First Touch placement policy allocates the data page in the memory closest to the thread accessing this page for the first time

This policy is the default on Linux and other OSes

It is the right thing to do for a sequential application

It is not always the right choice in a parallel application though

The data may end up on a single node

Leveraging First Touch

A first step towards tuning for NUMA is to avoid that all data ends up in the memory of a single node

This can easily happen if the data initialization is sequential

A single thread then touches the data and sets the home node

Luckily, often there is an easy solution

An Example

Parallelize the data initialization part!

```
#pragma omp parallel for schedule(static)
for (int i=0; i<n; i++)
    a[i] = 0;
```

Each thread has a slice of vector "a" in its local memory*

**) The allocation is on a virtual memory page basis*

Thread Affinity

Thread affinity provides for a way to specify where threads should execute

Such controls are often used to get threads close to their data

On Linux, tools like "numactl" can be used for this

OpenMP provides its own set of affinity controls

Other Scenarios to Watch Out For

In case data is read from file, a redundant parallel initialization can do magic, because this defines the home node(s) in advance

A malloc() call does not touch the data

Make sure that the thread that needs this block, initializes it

A calloc() call outside of a parallel region may cause the data to be on a single node

Wrapping Things Up

Hopefully this talk has helped to clarify what NUMA is about

We also introduced some key concepts related to NUMA

In the second part of this talk, we show how OpenMP can be used to leverage a NUMA architecture

Thank You And … Stay Tuned!

Bad OpenMP
Does Not Scale

Ruud van der Pas

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