# Speed Up Your OpenMP Code Without Doing Much


**Ruud van der Pas**
**Distinguished Engineer**

*Oracle Linux and Virtualization Engineering*
*Oracle, Santa Clara, CA, USA*


SC19 Denver, CO | hpc is now.

OpenMP™

# Agenda

- *Motivation*
- *Low Hanging Fruit*
- *A Case Study*

# Motivation




*"Speed Up Your OpenMP Code Without Doing Much"*

# OpenMP and Performance

***You can get good performance with OpenMP***

***And your code will scale***

***If you do things in the right way***

***Easy =/= Stupid***

# Ease of Use ?

| |
|---|
| *The ease of use of OpenMP is a mixed blessing (but I still prefer it over the alternative)* |
| *Ideas are easy and quick to implement* |
| *But some constructs are more expensive than others* |
| *Often, a small change can have a big impact* |
| *In this talk we show some of this low hanging fruit* |

# *Low Hanging Fruit*




*"Speed Up Your OpenMP Code Without Doing Much"*

# About Single Thread Performance and Scalability

***You have to pay attention to single thread performance***

***Why? If your code performs badly on 1 core, what do you think will happen on 10 cores, 20 cores, … ?***

***Scalability can mask poor performance!***
***(a slow code tends to scale better …)***

# The Basics For All Users

***Do not parallelize what does not matter***

***Never tune your code without using a profiler***

***Do not share data unless you have to***
***(in other words, use private data as much as you can)***

***One "parallel for" is fine. More is EVIL.***

***Think BIG***
***(maximize the size of the parallel regions)***

# The Wrong and Right Way Of Doing Things

```
#pragma omp parallel for
 { <code block 1> }
        ⋮
#pragma omp parallel for
 { <code block n> }
```

*Parallel region overhead repeated “n” times*
*No potential for the “nowait” clause*

```
#pragma omp parallel
{
    #pragma omp for
    { <code block 1> }
            ⋮
    #pragma omp for nowait
    { <code block n> }
} // End of parallel region
```

*Parallel region overhead only once*
*Potential for the “nowait” clause*

# More Basics

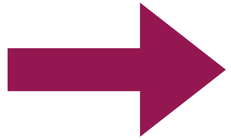
***Every barrier matters***
***(and please use them carefully)***

***The same is true for locks and critical regions***
***(use atomic constructs where possible)***

***EVERYTHING Matters***
***(minor overheads get out of hand eventually)***

# Another Example

```
#pragma omp single
{
  <some code>
} // End of single region

#pragma omp barrier

  <more code>
```



```
#pragma omp single
{
  <some code>
} // End of single region

#pragma omp barrier

  <more code>
```

***The second barrier is redundant because the single construct has an implied barrier already***

***(this second barrier will still take time though)***

# One More Example

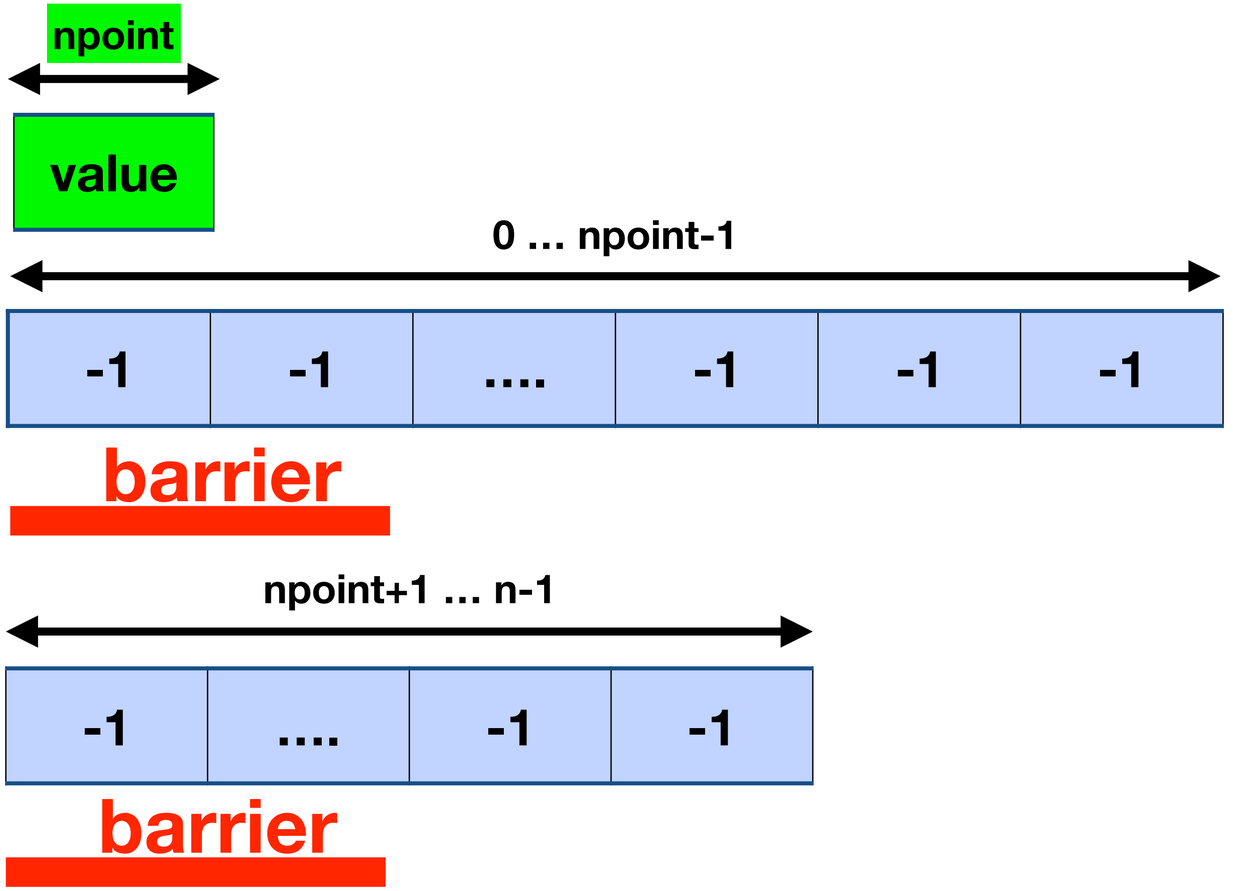
```
a[npoint] = value;
#pragma omp parallel …
{
   #pragma omp for
     for (int64_t k=0; k<npoint; k++)
       a[k] = -1;
   #pragma omp for
     for (int64_t k=npoint+1; k<n; k++)
       a[k] = -1;

   <more code>

} // End of parallel region
```

# What Is Wrong With This?

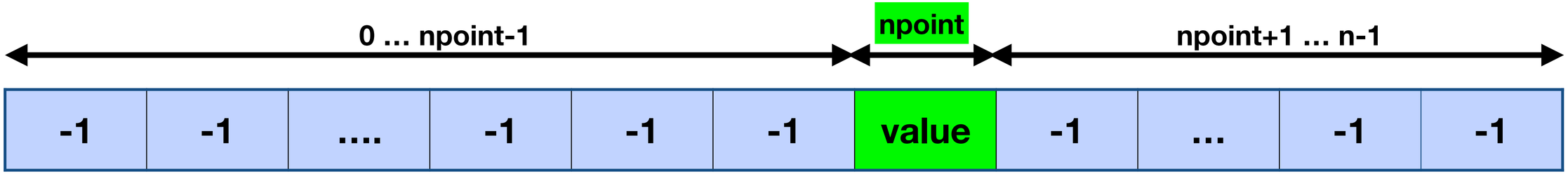
```
a[npoint] = value;
#pragma omp parallel …
{
  #pragma omp for
    for (int64_t k=0; k<npoint; k++)
      a[k] = -1;
  #pragma omp for
    for (int64_t k=npoint+1; k<n; k++)
      a[k] = -1;
  <more code>

} // End of parallel region
```

- ✓ *There are 2 barriers*
- ✓ *Two times serial and parallel overhead*
- ✓ *Performance benefit depends on the value of “npoint” and “n”*

# The Sequence Of Operations



# The Actual Operation Performed



# The Modified Code

```
#pragma omp parallel …
{
  #pragma omp for
    for (int64_t k=0; k<n; k++)
      a[k] = -1;

  #pragma omp single nowait
    {a[npoint] = value;}

  <more code>

} // End of parallel region
```

- ✓ *Only one barrier*
- ✓ *One time serial and parallel overhead*
- ✓ *Performance benefit depends on the value of “n” only*

# *A Case Study*

# The Application

***The OpenMP reference version of the Graph 500 benchmark***

***Structure of the code:***

- ***Construct an undirected graph of the specified size***
- ***Randomly select a key and conduct a BFS search***
- ***Verify the result is a tree***

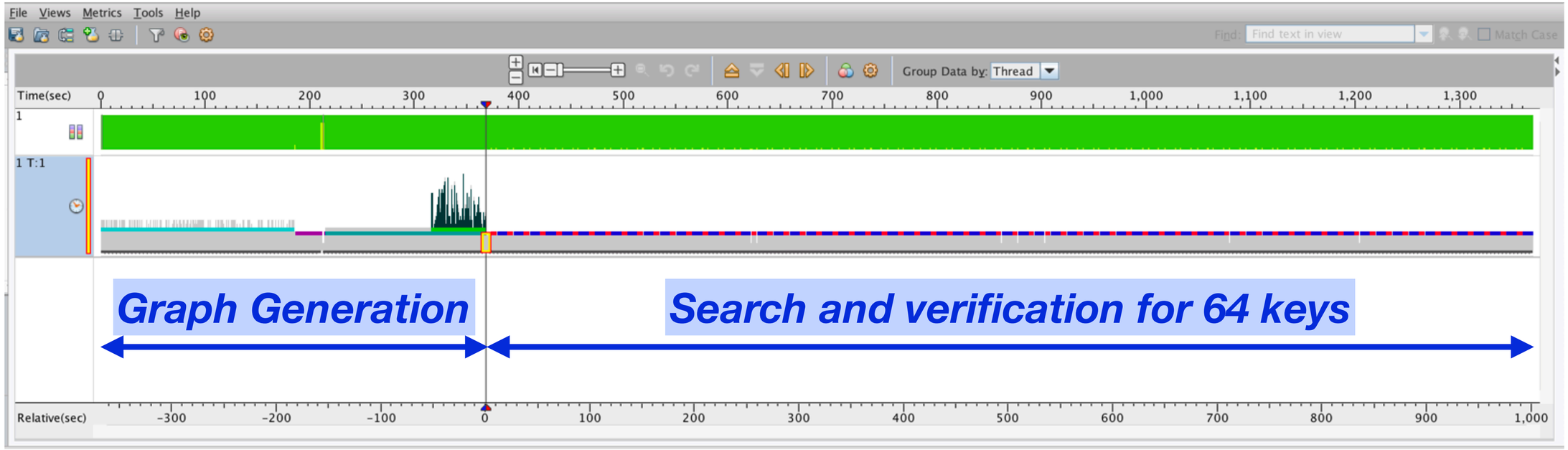
**Repeat <n> times**

***For the benchmark score, only the search time matters***

# Testing Circumstances

- *The code uses a parameter SCALE to set the size of the graph*
- *The value used for SCALE is 24 (~9 GB of RAM used)*
- *All experiments were conducted in the Oracle Cloud (“OCI”)*
- *Used a VM instance with 1 Skylake socket (8 cores, 16 threads)*
- *Operating System: Oracle Linux; compiler: gcc 8.3.1*
- *The Oracle Performance Analyzer was used to make the profiles*

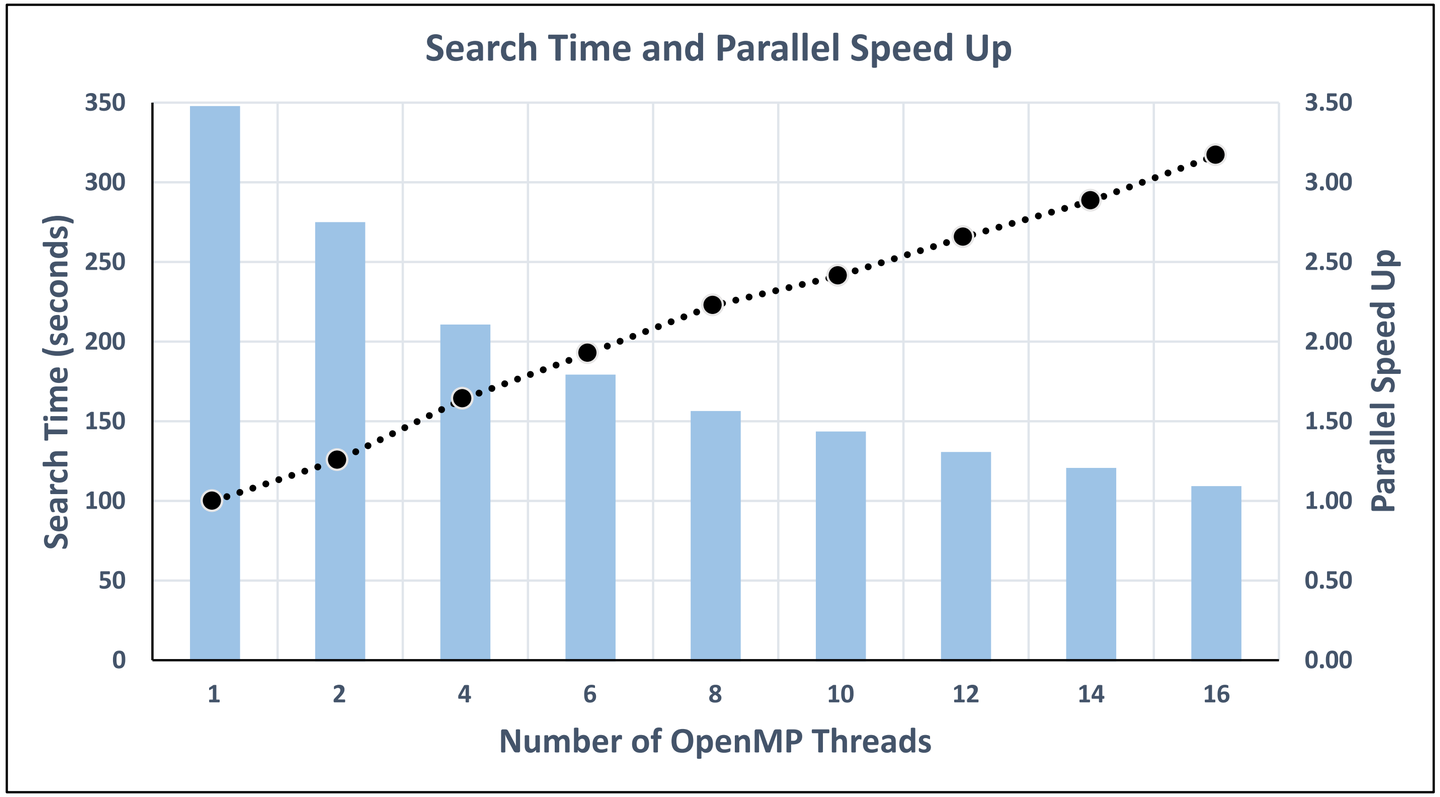
# The Dynamic Behaviour





***Note: The Oracle Performance Analyzer was used to generate this time line***

# The Performance For SCALE = 24 (9 GB)




- ✓ *Search time reduces as threads are added*
- ✓ *Benefit from all 16 (hyper) threads*
- ✓ *But the 3.2x parallel speed up is disappointing*

# Action Plan

***Used a profiling tool* to identify the time consuming parts***

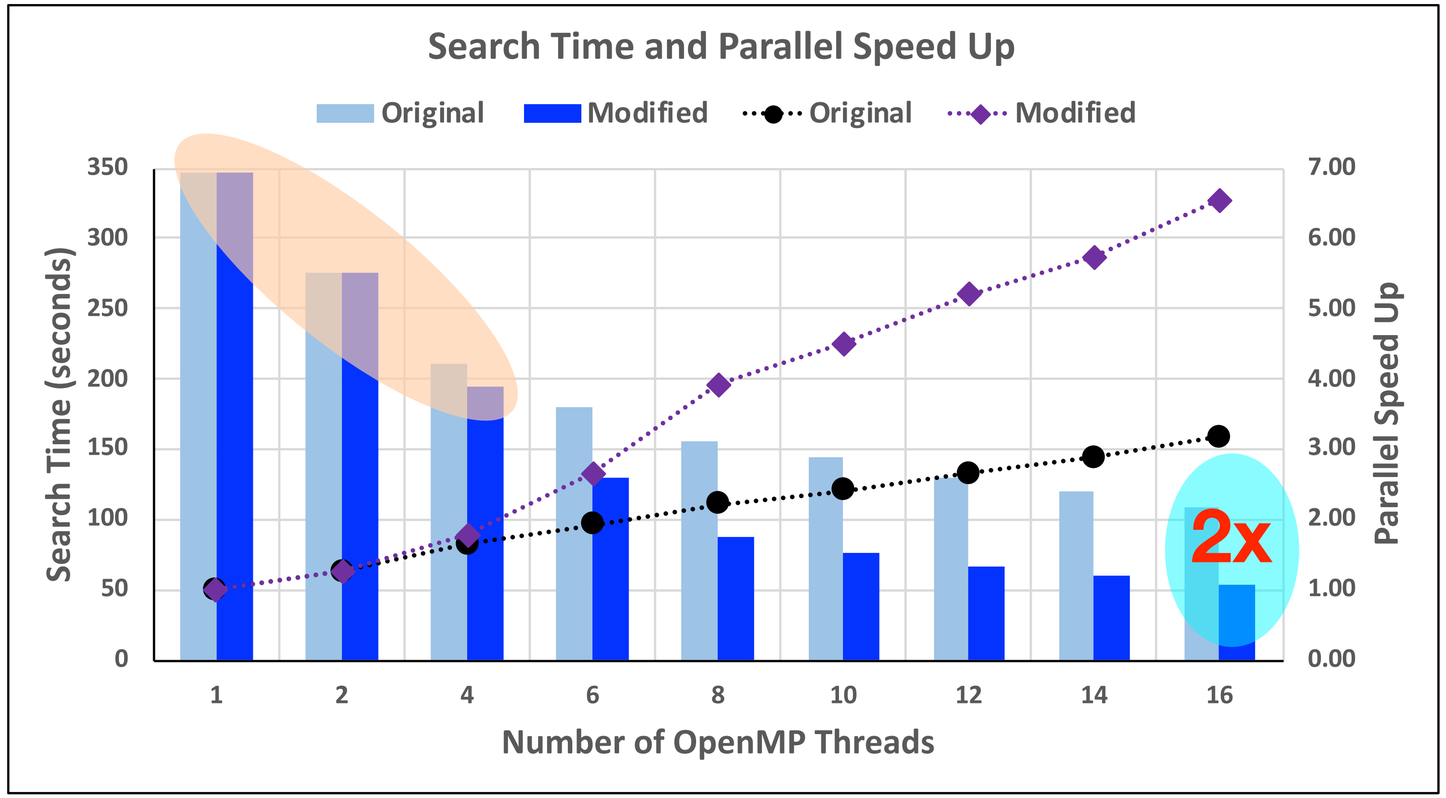
***Found several opportunities to improve the OpenMP part***

***These are actually shown earlier in this talk***

***Although simple changes, the improvement is substantial:***

**) Use your preferred tool; we used the Oracle Performance Analyzer*

# Performance Of The Original and Modified Code




- ✓ *A noticeable reduction in the search time at 4 threads and beyond*
- ✓ *The parallel speed up increases to 6.5x*
- ✓ *The search time is reduced by 2x*

# Are We Done Yet?

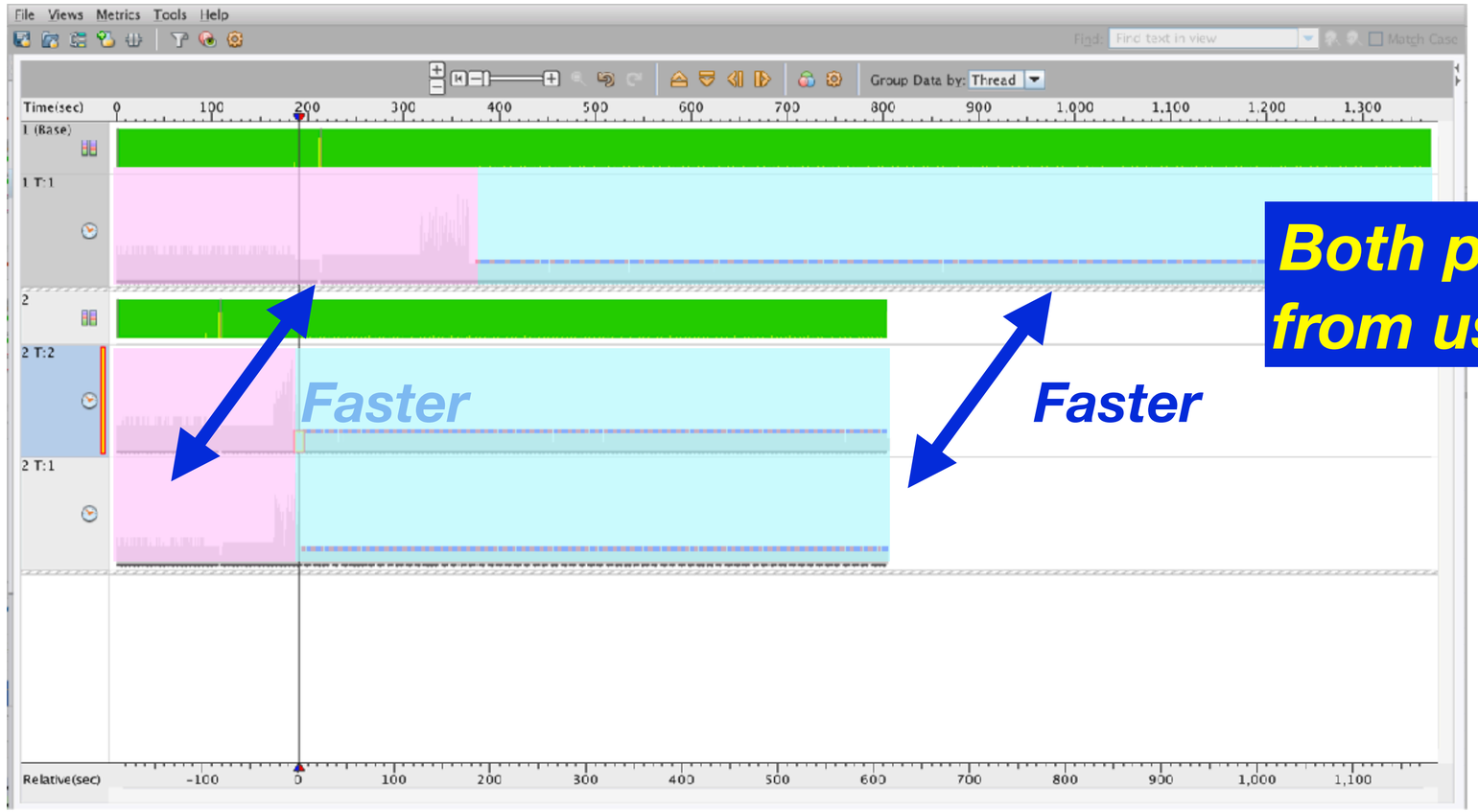
***The 2x reduction in the search time is encouraging***

***The efforts to achieve this have been limited***

***The question is whether there is more to be gained***

***Let's look at the dynamic behaviour of the threads:***

# A Comparison Between 1 And 2 Threads



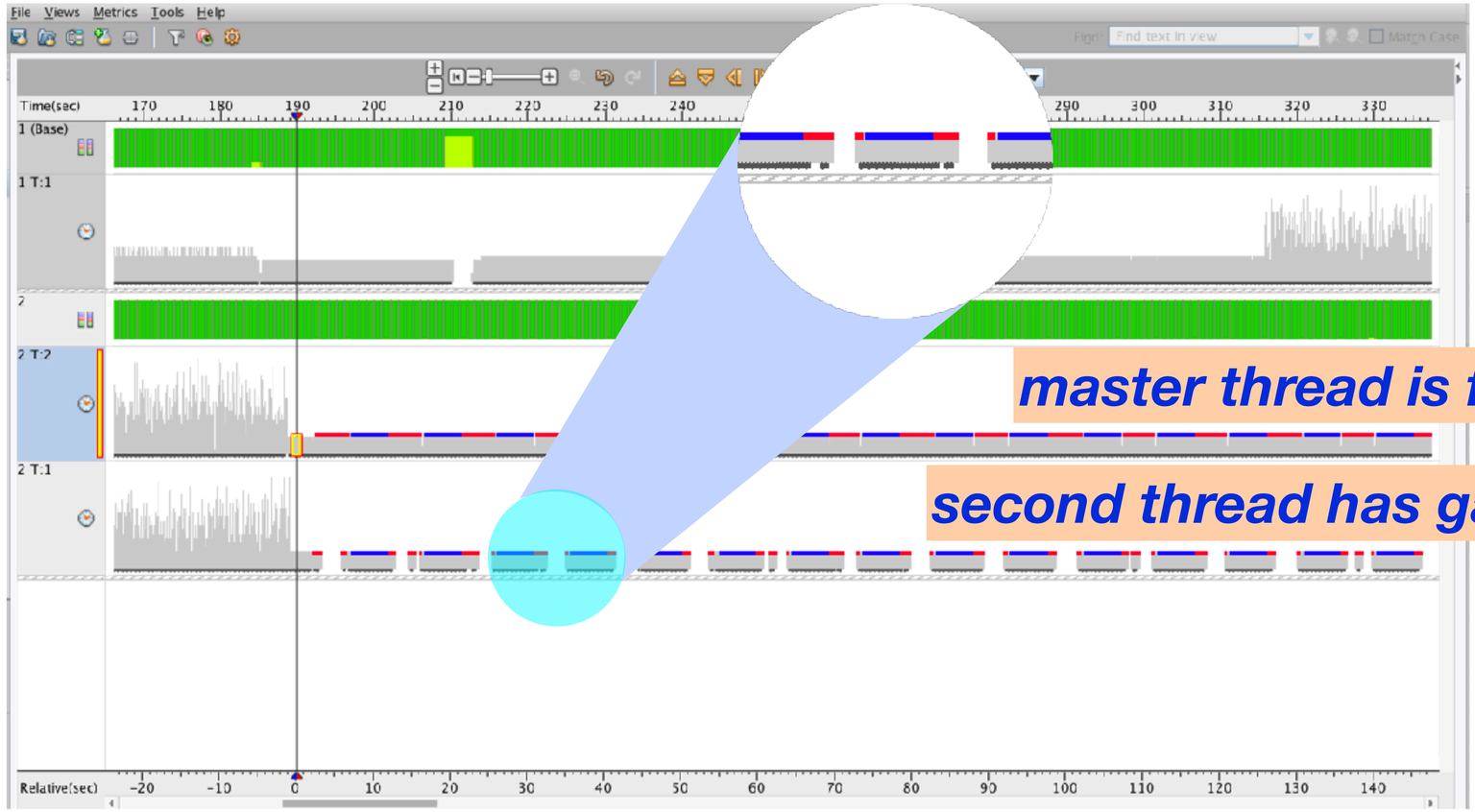

**Both phases benefit from using 2 threads**

Search

Verification

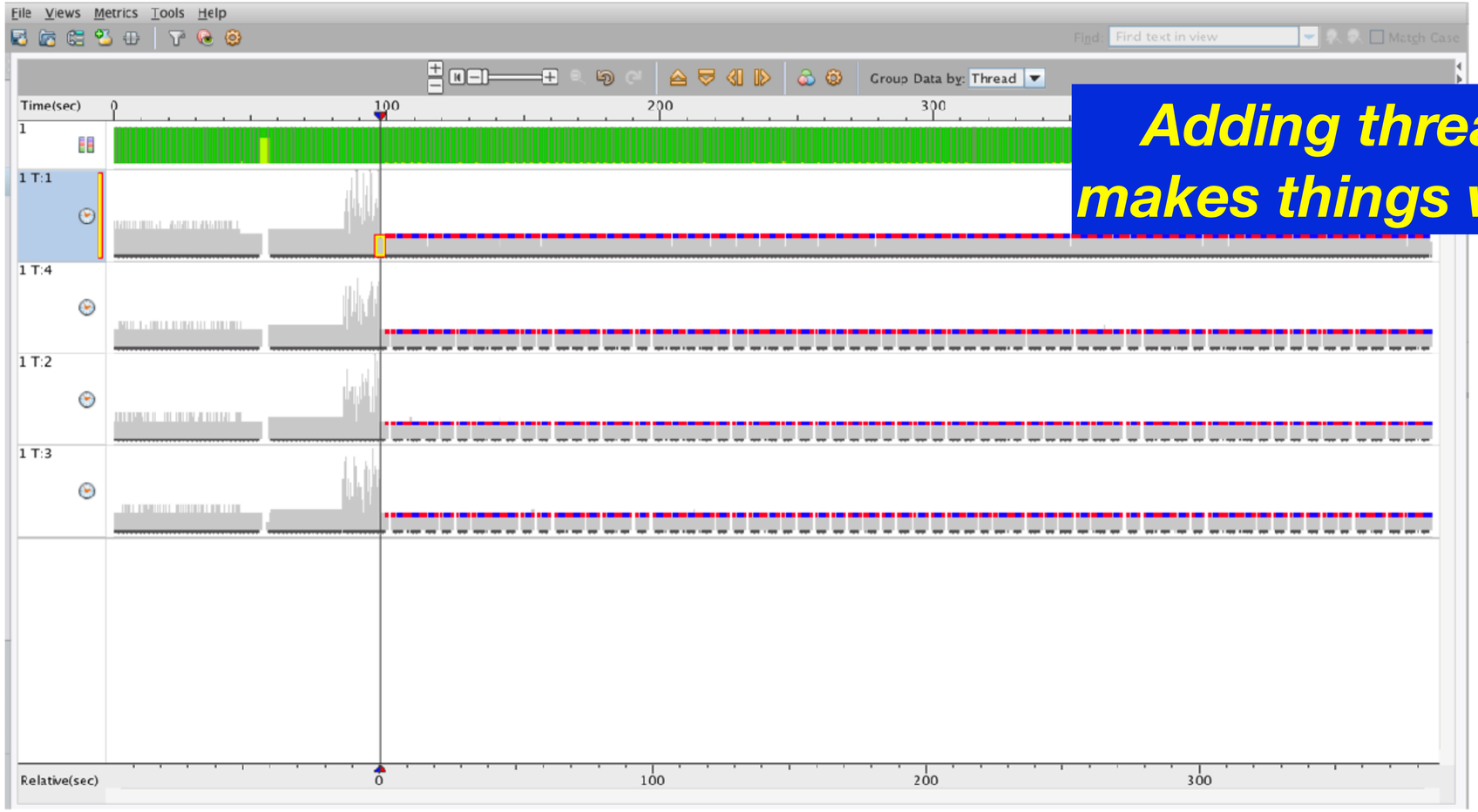
***Note: The Oracle Performance Analyzer was used to generate this time line***

# Zoom In On The Second Thread




***Note: The Oracle Performance Analyzer was used to generate this time line***

# How About 4 Threads?




**Adding threads makes things worse**

***Note: The Oracle Performance Analyzer was used to generate this time line***

# The Problem

```
#pragma omp for
for (int64_t k = k1; k < oldk2; ++k) {
        <code>
  for (int64_t vo = 1 ; vo < veo; ++vo) {
        <more code>
    if (bfs_tree[j]
      <even more code and irregular >
    } // End of if
  } // End of for-loop on vo
} // End of parallel for-loop on k
```

*Load Imbalance!*

*Regular, structured parallel loop*

*Irregular loop*

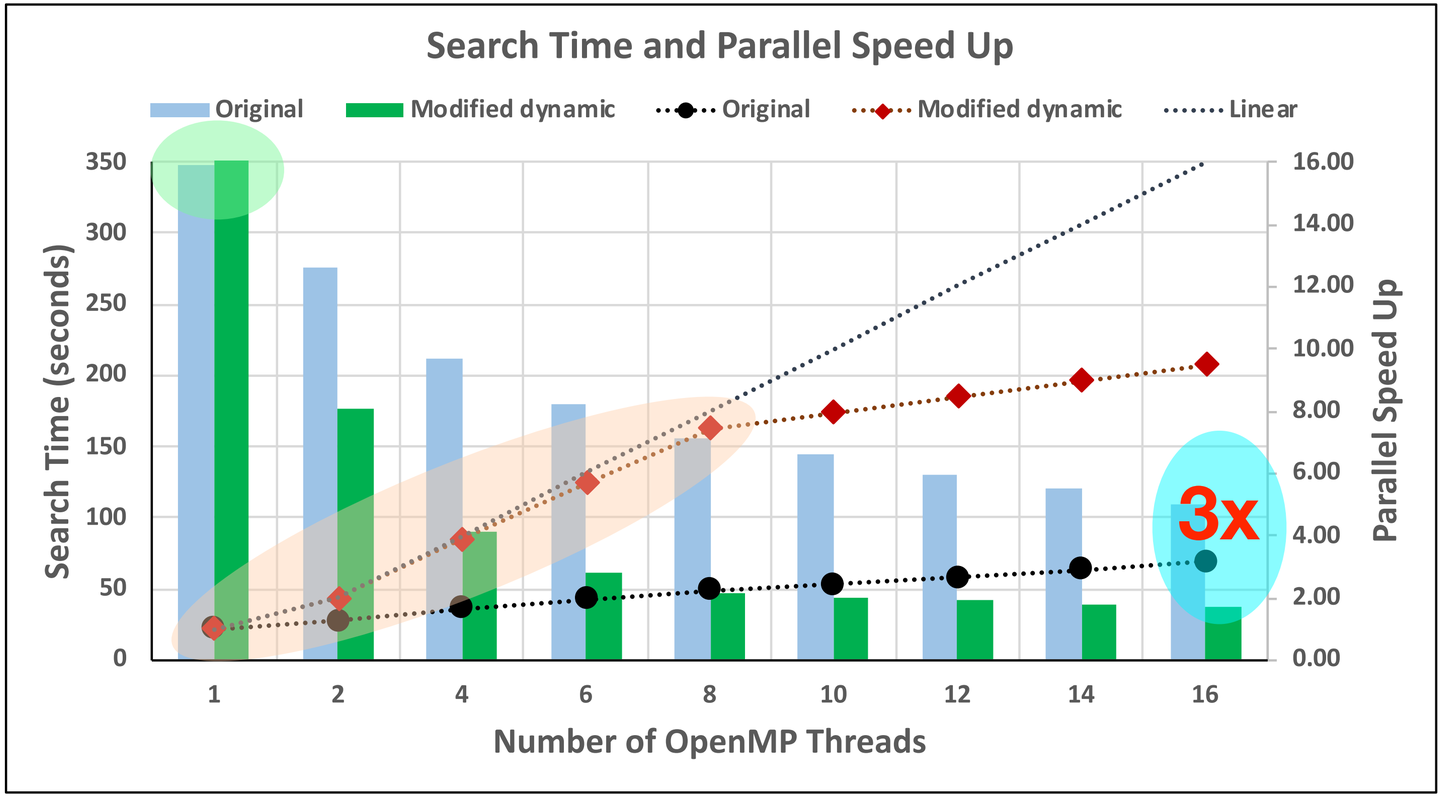
*Unbalanced flow*

# The Solution

$ export OMP_SCHEDULE="dynamic,25"

```
#pragma omp for schedule(runtime)
for (int64_t k = k1; k < oldk2; ++k) {\
        <code>
  for (int64_t vo = XOFF(v); vo < veo; ++vo) {
        <more code>
    if (bfs_tree[j] == -1) {
      <even more code and irregular >
    } // End of if
  } // End of for-loop on vo
} // End of parallel for-loop on k
```

# The Performance With Dynamic Scheduling Added




- ✓ *A 1% slow down on a single thread*
- ✓ *Near linear scaling for up to 8 threads*
- ✓ *The parallel speed up increased to 9.5x*
- ✓ *The search time is reduced by 3x*



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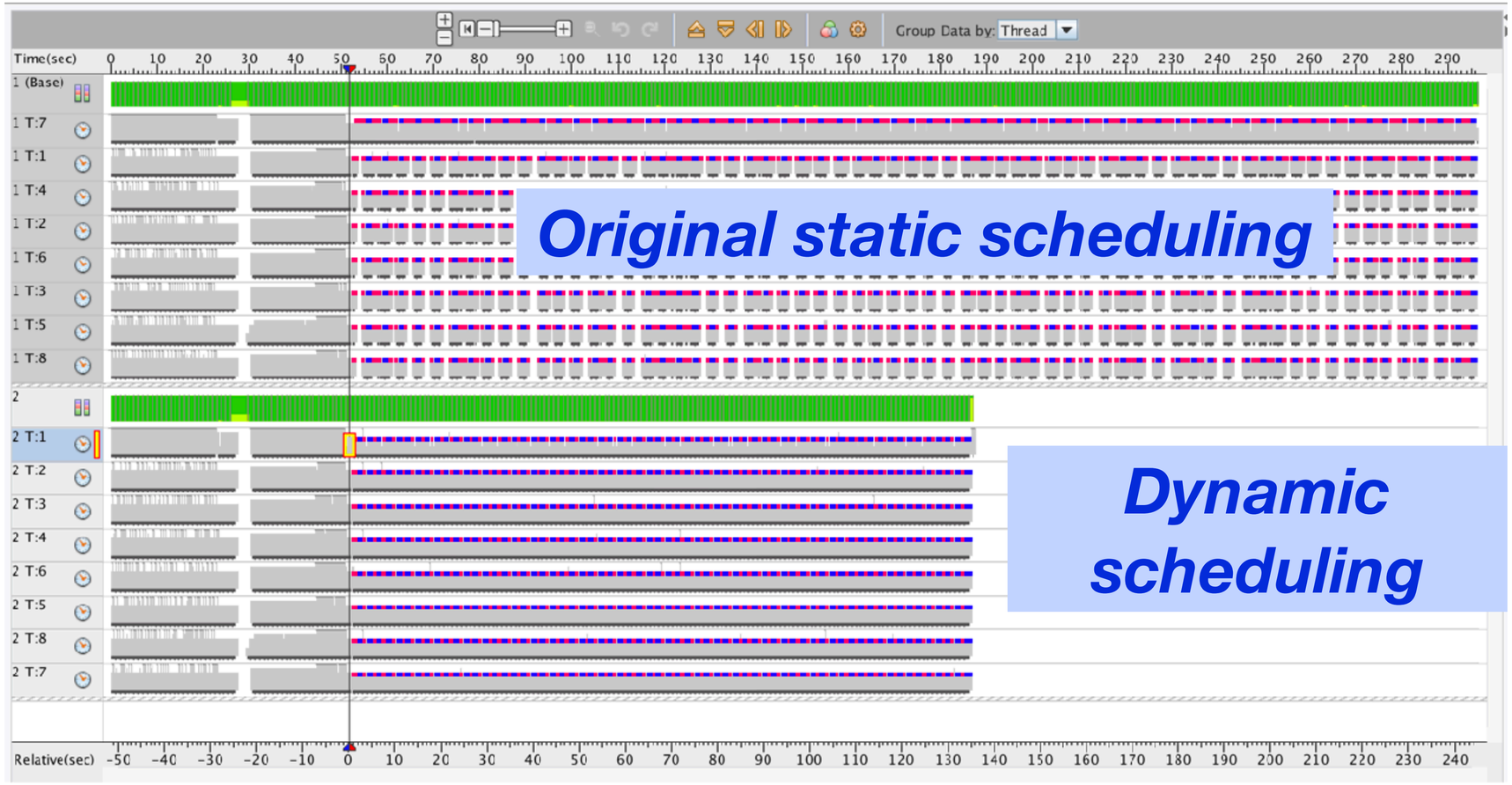
# The Improvement




***Note: The Oracle Performance Analyzer was used to generate this time line***

# Conclusions

***A good profiling tool is indispensable when tuning applications***

***With some simple improvements in the use of OpenMP, a 2x reduction in the search time is realized***

***Compared to the original code, adding dynamic scheduling reduces the search time by 3x***


Thank You And … Stay Tuned!
Ruud van der Pas
Distinguished Engineer
Oracle Linux and Virtualization Engineering
Oracle, Santa Clara, CA, USA
SC19
Denver, CO
hpc is now.
OpenMP