# Parallel and Distributed Systems

Bitonic Sorter

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## *Abstract*

This project is about a parallel implementation of the Bitonic Sort algorithm. The algorithm was implemented using pthreads, OpenMP, CilkPlus in C language and the results was compared against *qsort* function from *stdlib.h* library and a serial implementation of bitonic sort.

## *Algorithm*

The program takes as input the parameters p and q. It then creates $2^p$ threads, and an array of random elements, with length $2^q$. Finally, it sorts the elements and checks the correctness of the result.

The pseudo-code of the algorithm, to implement the actual sorting, is presented in the following box.

```
1.      Make some initial calculations.
2.      If the current number of threads < max number of threads
3.                  Create a new thread.
4.                  Assign to new thread: rec_bitonic_sort( left )
5.      else
6.                  Execute rec_bitonic_sort( left )
7.      end_if
8.
9.      Execute rec_bitonic_sort( right )
10.     Execute bitonic_merge
```

In the critical section of the code, that is access to shared memory, a mutex variable was used.

Furthermore, an optimized version of the algorithm was implemented by combining bitonic sort with qsort. More specifically, sorting of sub-arrays with length less than $2^{21}$ qsort was used. This resulted in an important decrease in execution time.

Finally, in addition to pthreads, the equivalent OpenMP and Cilk Plus implementations were written and we compared the results.

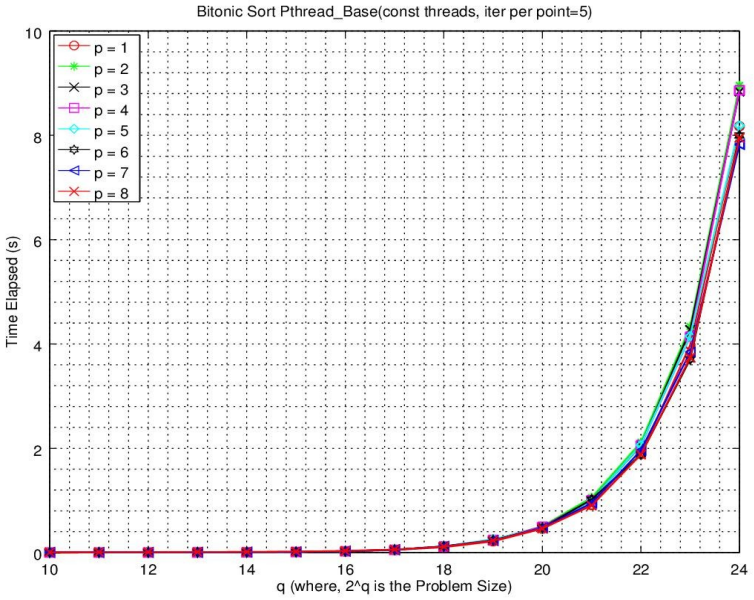
## *Correctness check*

Functional correctness was confirmed, after comparing the output of the algorithm with the output of *qsort* function from *stdlib.h*.

## *Results*

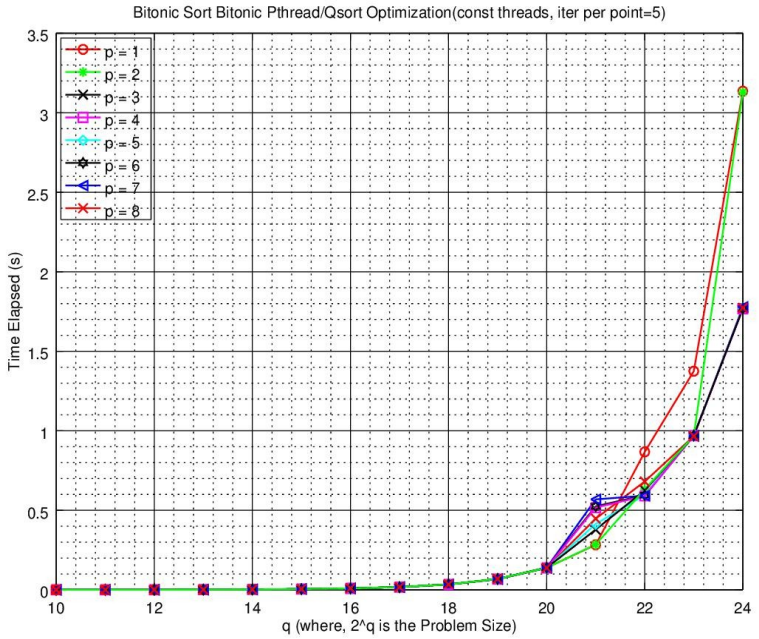
The experiments were carried out on diades system (Intel Xeon CPU @2.5GHz, 8 cores) of AUTh. Each experiment was executed 5 times and we took the mean result.

First, we present the diagram of time/probem size for curves of constant p, and for the case of pthreads.




*Drawing 1: Bitonic Sort - Pthreads Recursive (basic)*

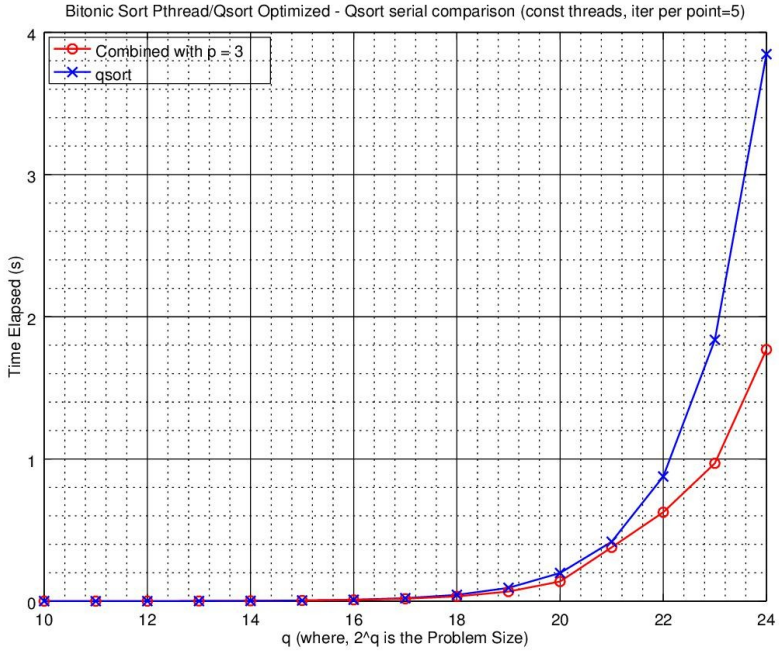
When we use the combination of bitonic sort and qsort the time is reduced, as can be seen from the next diagram.




*Drawing 2: Bitonic Sort - Pthreads Recursive (optimized)*

From the corresponding OpenMP and Cilk Plus diagrams we can see a similar trend. They are attached in the system files.

Moreover, we present a comparison with qsort and the optimal solution which was achieved for 8 threads and with the combination of bitonic sort and qsort, where we see a clear reduction in execution time.




*Drawing 3: Bitonic Sort (Pthreads Optimal) - Qsort comparison*

Finally we present the table with execution time for q = 24, και p = 3. The parallel_threshold (combination of bitonic sort with qsort), was $2^{21}$.

| Algorithm | Time (s) |
|---|---|
| Bitonic Serial imperative | 16.8350 |
| Bitonic Serial recursive | 11.4940 |
| Bitonic Parallel pthreads - basic | 8.8353 |
| Bitonic Parallel pthreads – qsort optimization | 1.7692 |
| Bitonic Parallel OpenMP – qsort optimization | 5.3690 |
| Bitonic Parallel CilkPlus – qsort optimization | 1.9072 |
| Quick Sort stdlib.h | 3.8450 |

## *Conclusion*

A parallel bitonic sort algorithm was implemented and compared against the serial counterpart and qsort from stdlib.h. For the optimum case that both bitonic sort and qsort were combined the result was improved execution time in comparison with qsort.