Recent Research on the Cray XMT

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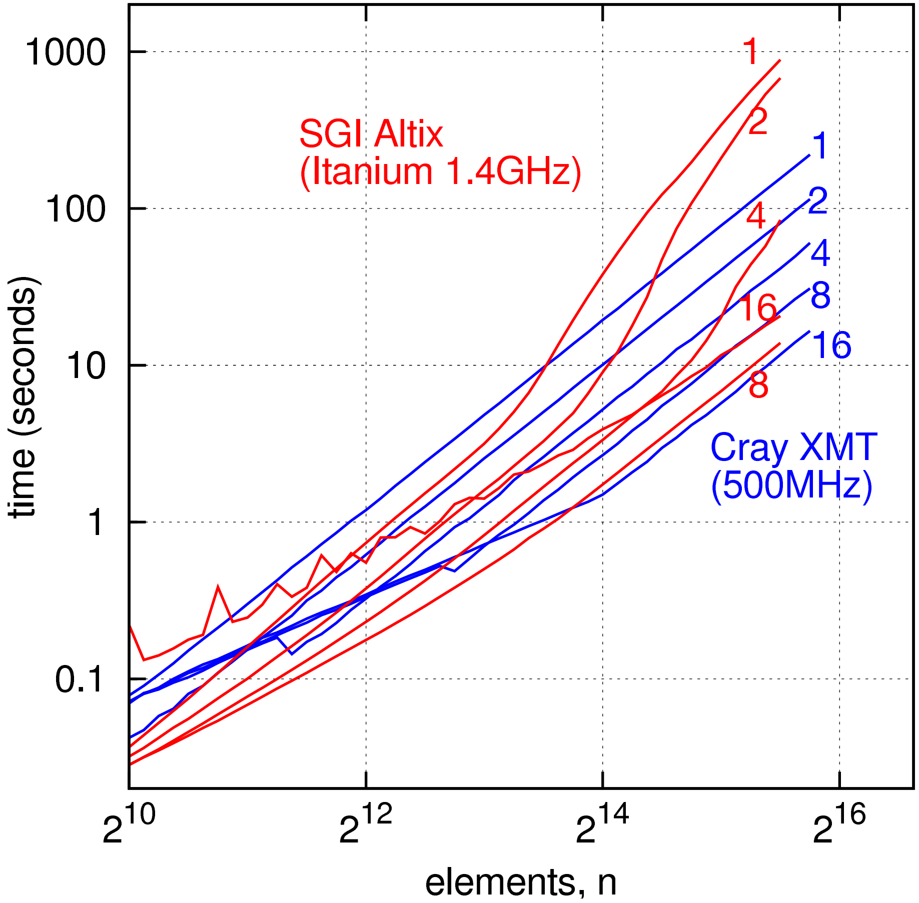
Example: Sequence Alignment

Ordinary C code–The compiler is reassured that P, T & D do not overlap:automatically converts rectangular loop into wavefronted loop.

```
         |    #pragma mta noalias *P, *T, *D
         |    for (i=1; i <=m; i++) {
         |       int j;
7 P:e    |       int myPi=P[i];
         |       for(j=1; j <= n ; j++){
         |          int v, h, d, m1, m2, p;
9 -P1:w  |          v= D[i-1][j]+1;
         |          p= (myPi!=T[j]);
9 -P1:w  |          ...
         |          m2 = MIN( m1,h);
9 P-:w   |          D[i][j] = m2;
9 SP1:w  +
         |        }
         |    }
```

Comparative Timings

Sequence alignment on the Cray XMT & SGI Altix



Concurrency & Computation

`www3.interscience.wiley.com/journal/122580907/abstract`

Graph Theoretic Model for Virus Reassortment

- Evolution over τ stages or seasons modeled with a layered or *multipartite* graph.
- Viruses = nodes
- Reassortment events = nodes
- Mutations/reassortment choices = edges
- Weights on edges represent edit distances

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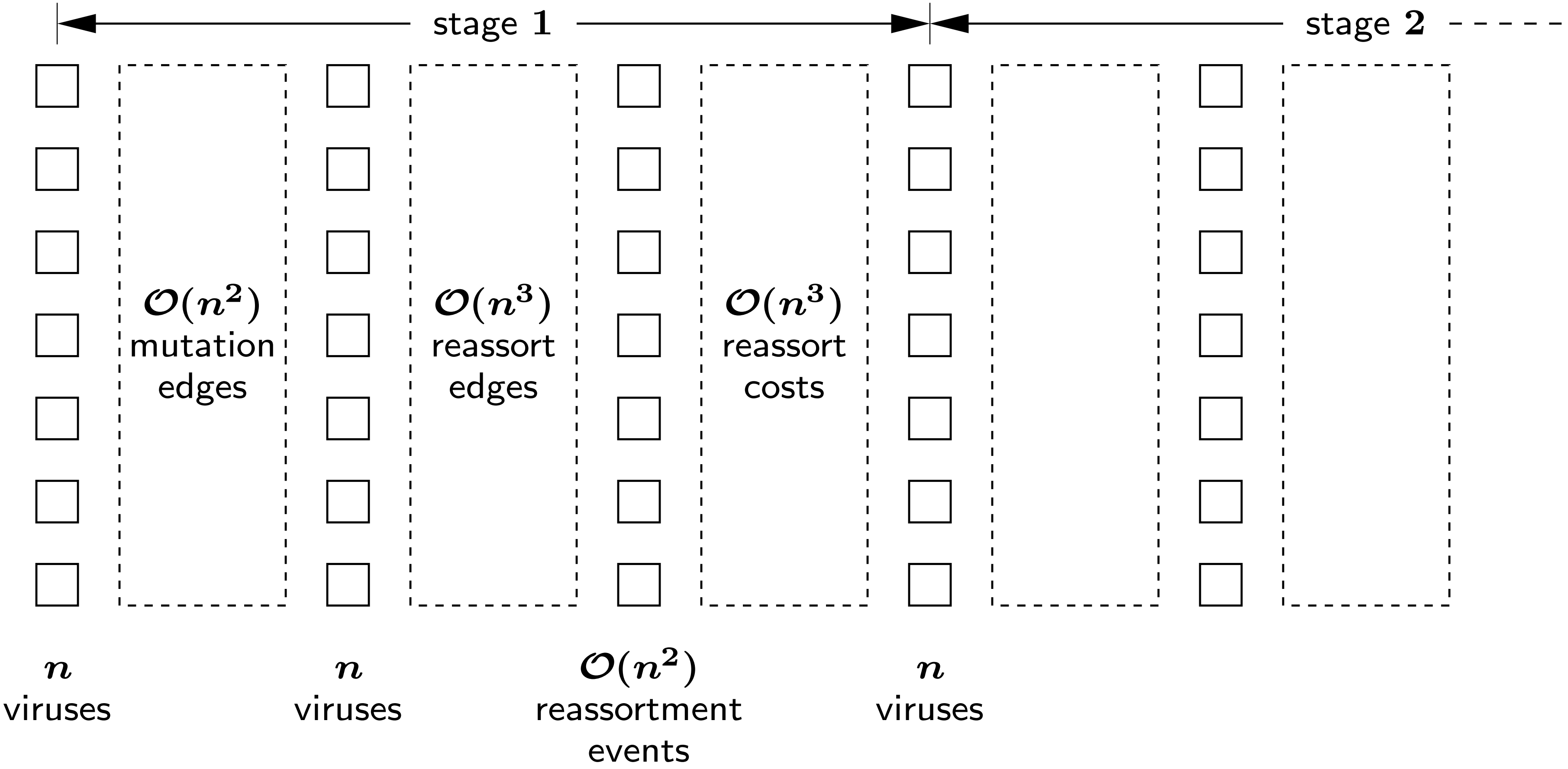
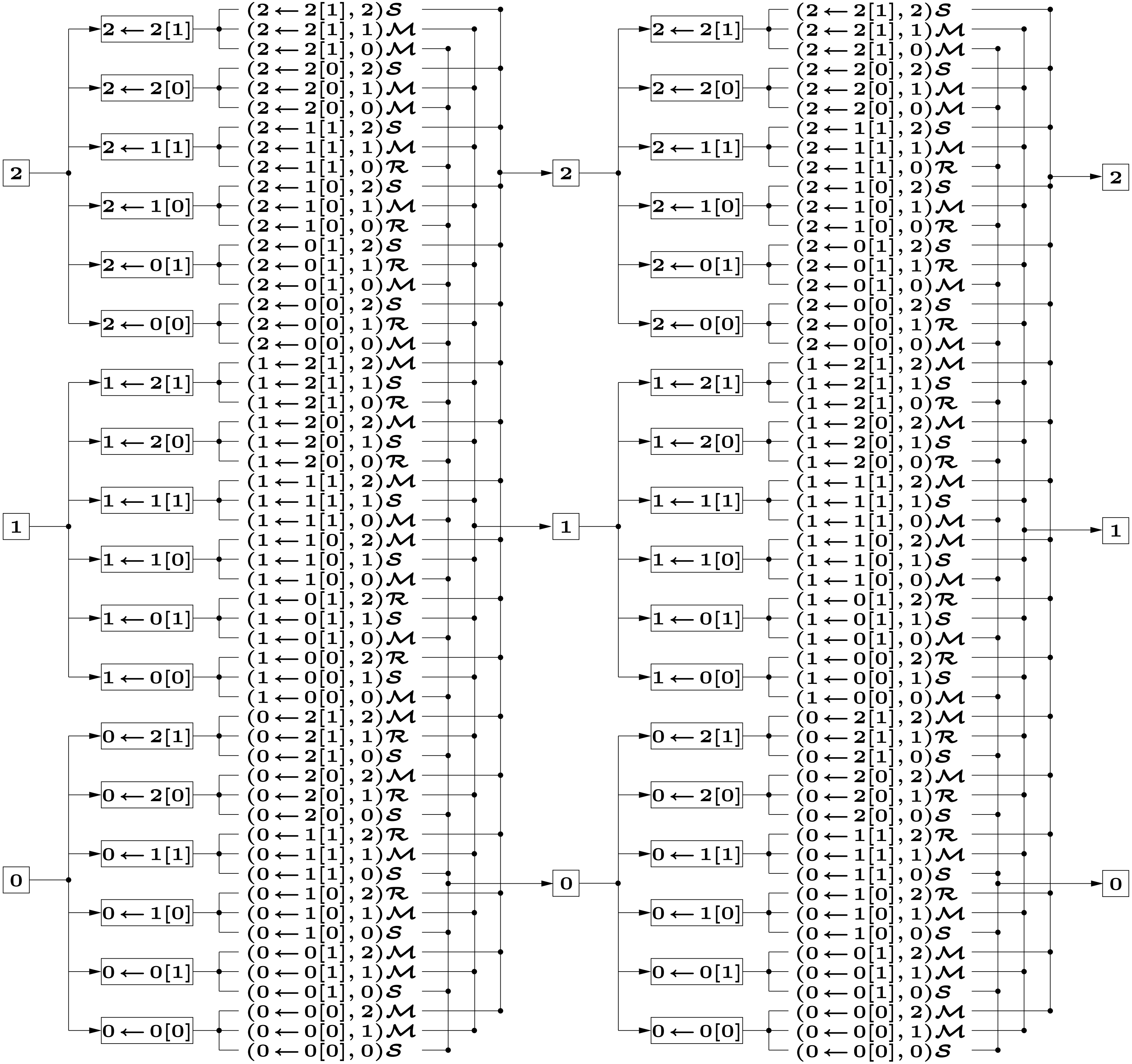
Reassortment Network


stage $\mathbf{1}$
stage $\mathbf{2}$
$\mathcal{O}(n^2)$ mutation edges
$\mathcal{O}(n^3)$ reassort edges
$\mathcal{O}(n^3)$ reassort costs
n viruses
n viruses
$\mathcal{O}(n^2)$ reassortment events
n viruses

Path in Reassortment Network corresponds to sequences of mutations and reassortments that transform one virus into another.

Network for
n =3 viruses,
τ =2 stages,
2 segments/virus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Path:

Virus 1

$1 \leftarrow 1[0]$ (stasis)

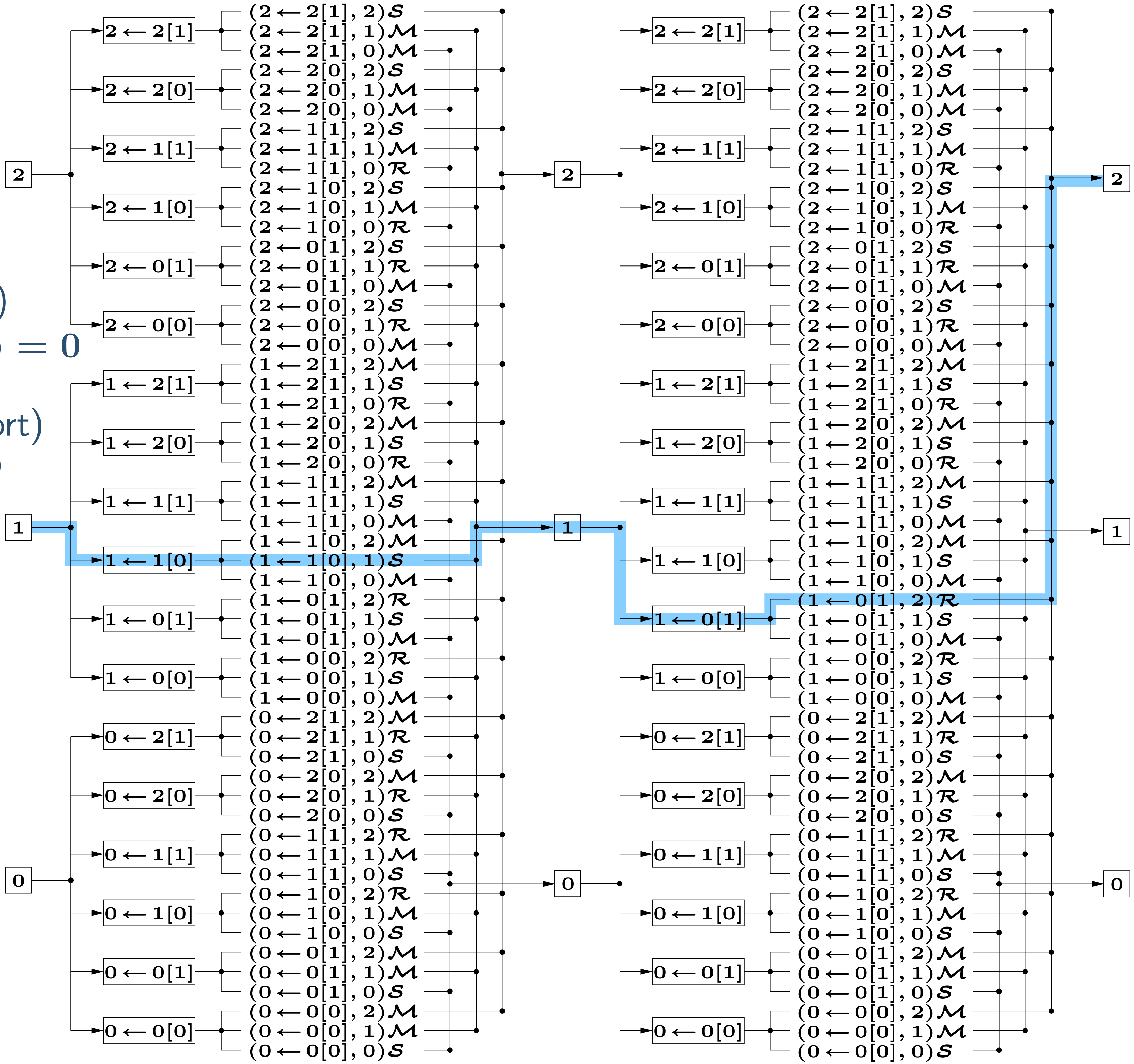
$\mathcal{W}(1 \leftarrow 1[0], 1) = 0$

Virus 1

$1 \leftarrow 0[1]$ (reassort)

$\mathcal{W}(1 \leftarrow 0[1], 2)$

Virus 2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Path:

Virus 1

$1 \leftarrow 1[0]$ (stasis)

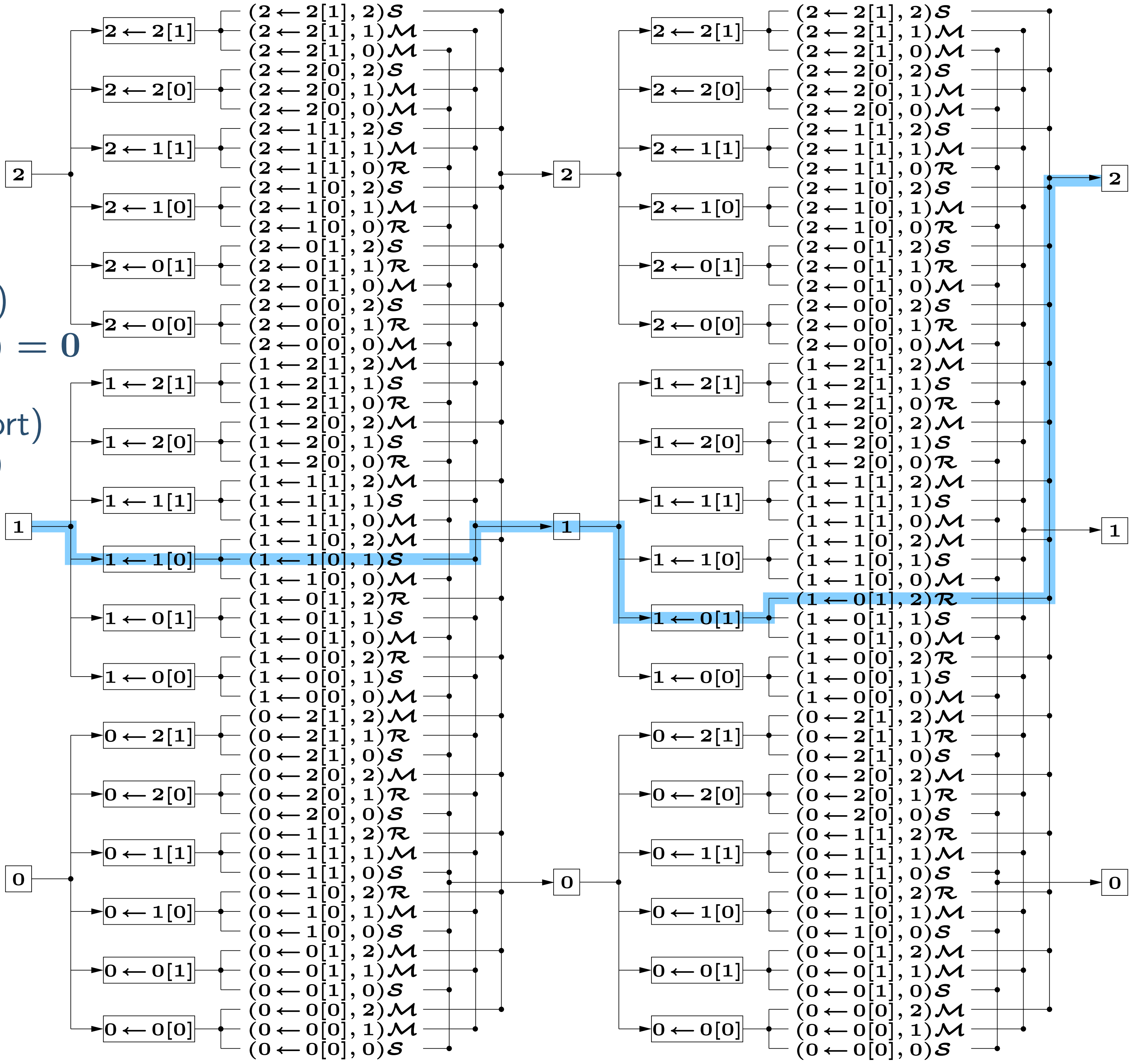
$\mathcal{W}(1 \leftarrow 1[0], 1) = 0$

Virus 1

$1 \leftarrow 0[1]$ (reassort)

$\mathcal{W}(1 \leftarrow 0[1], 2)$

Virus 2



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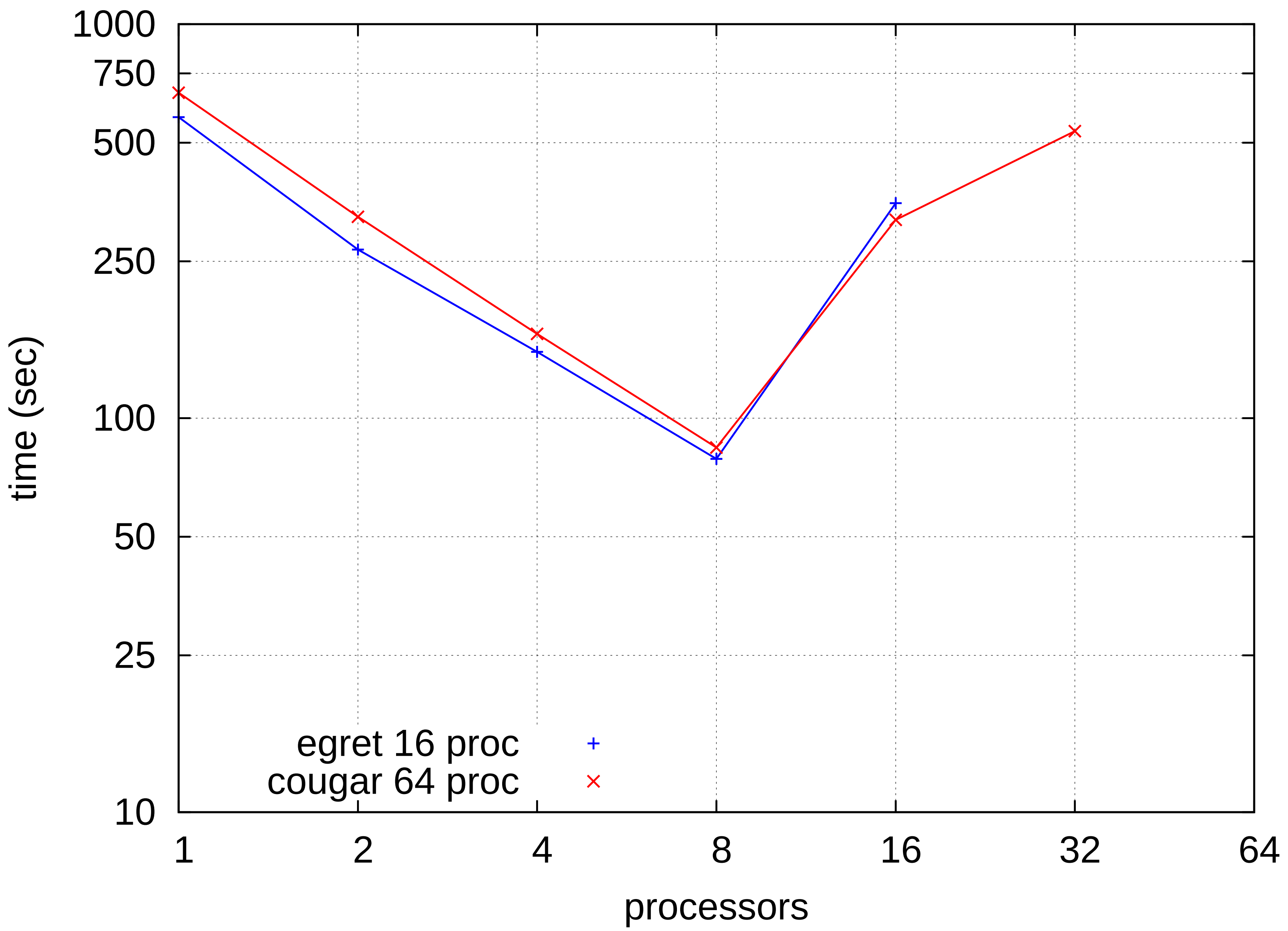
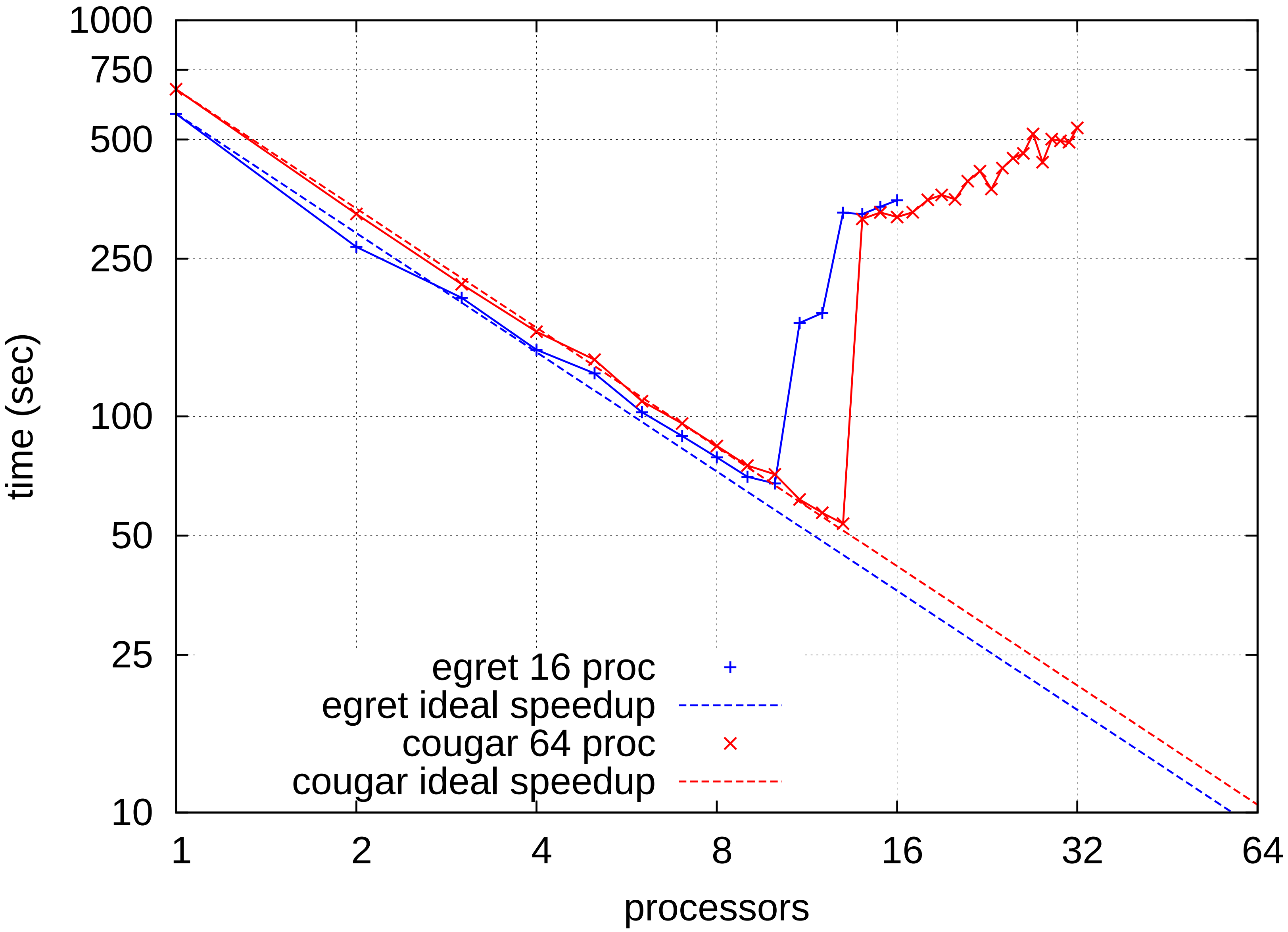
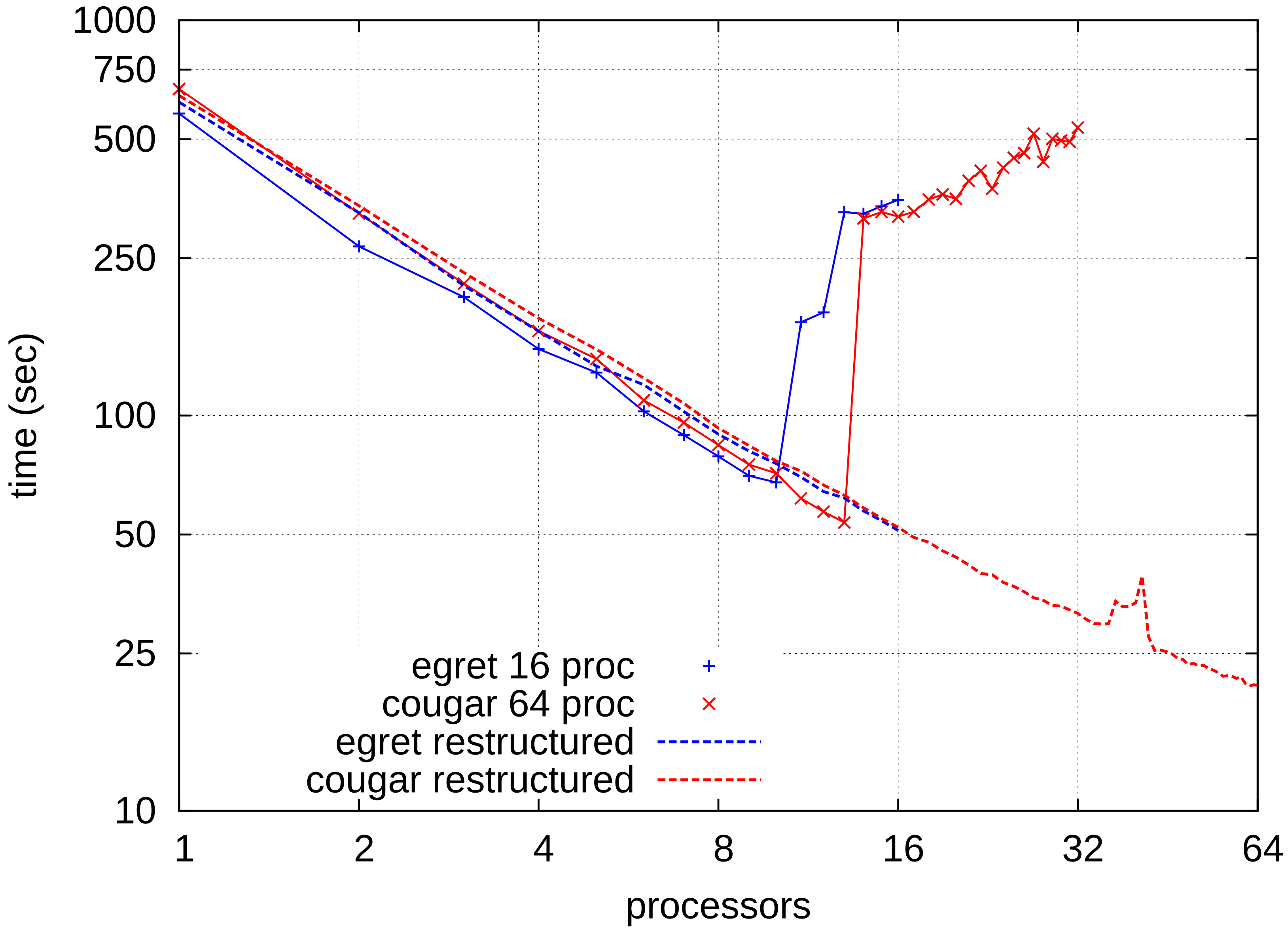
Comparative Timings



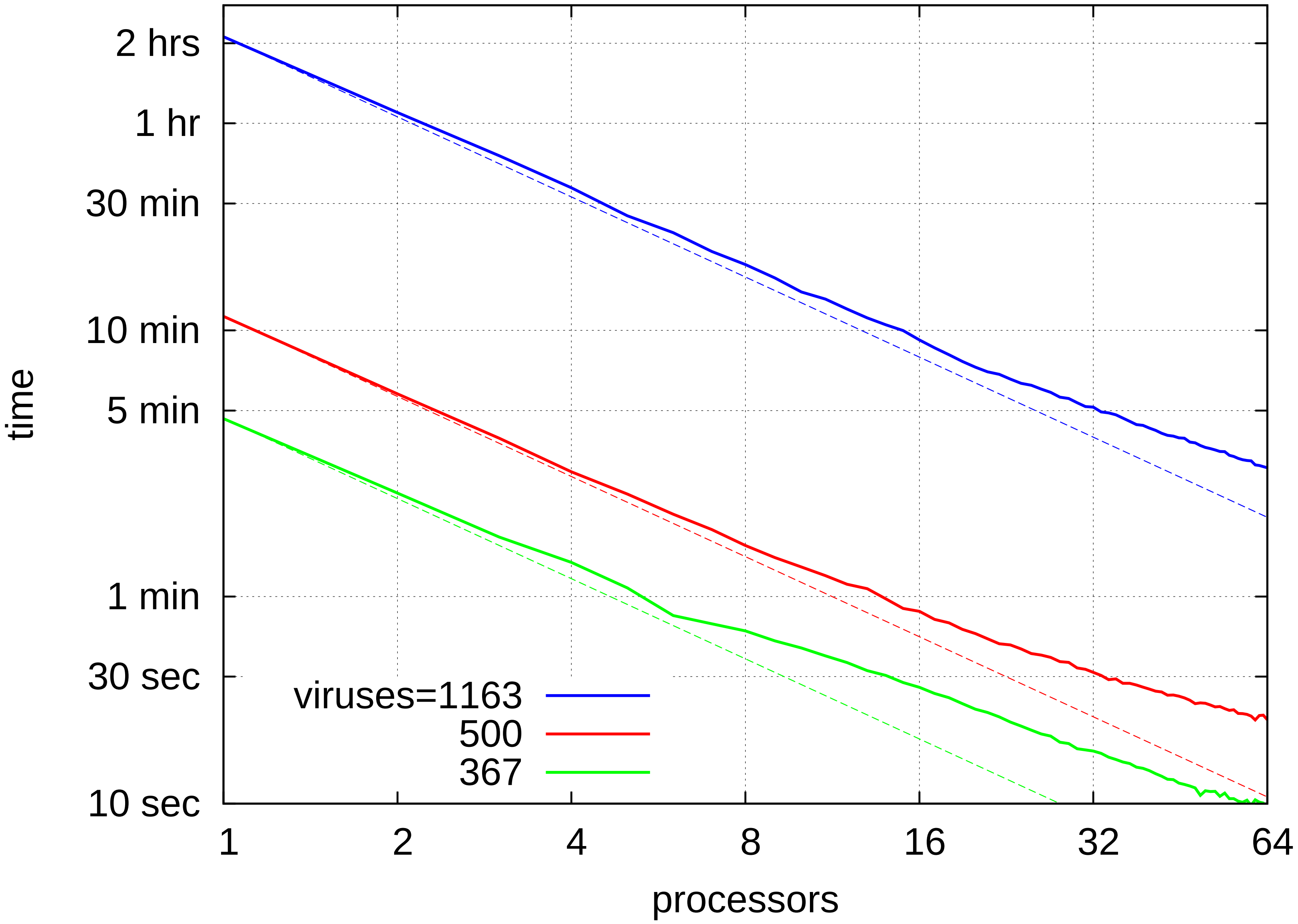
Comparative Timings



Comparative Timings



Timings (restructured code)



Shared Multilevel Parallel Queues

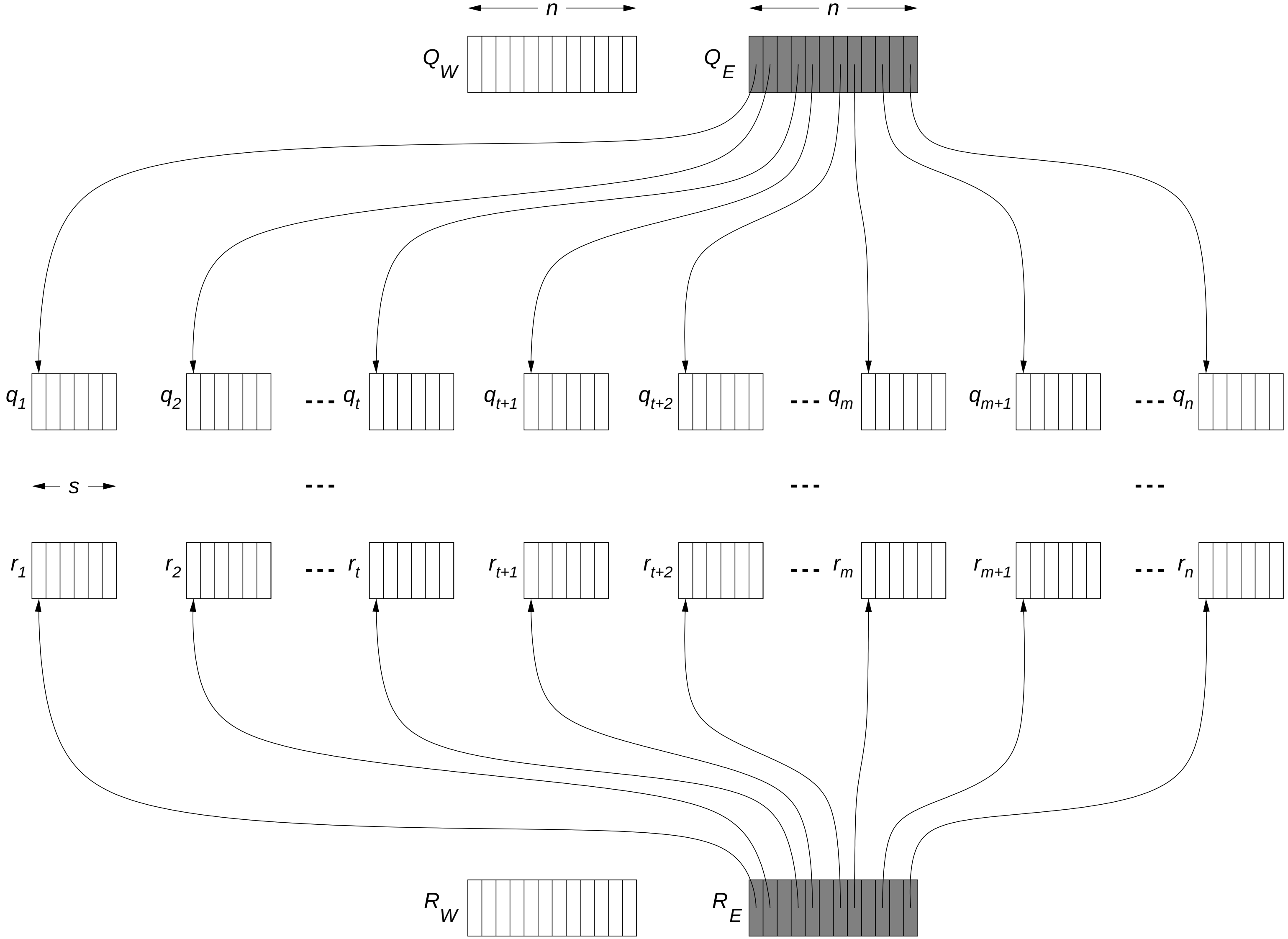
Motivation

- The use of parallel shared queues is essential for the correct execution of many classes of programs in parallel computers.
- Control of concurrent access to shared queues is possible with FETCH_AND_ADD or similar instructions. Unfortunately these instructions generate severe overhead as the number of threads increases.
- A *Shared Multilevel Parallel Queue (SMPQ)* mechanism has been developed that greatly reduces this overhead.

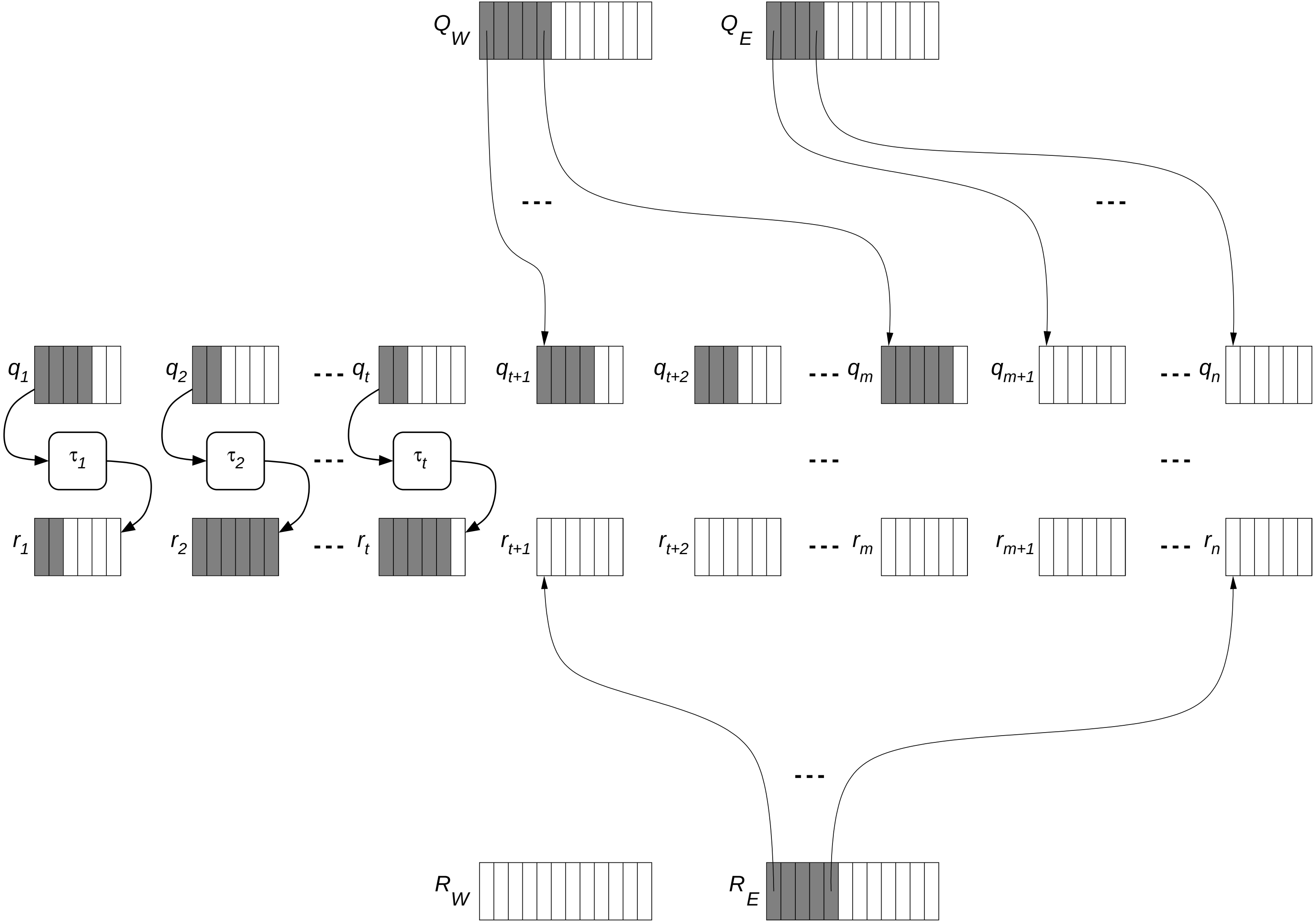
- While the FETCH_AND_ADD hardware will permit logically correct operation of shared queues, most parallel computer systems have a limited number of hardware units capable of carrying it out and the performance of queuing operations drops dramatically as the number of active threads increases.
- Consequently, the performance of many algorithms that require frequent use of the FETCH_AND_ADD operation is very limited and performance scales very poorly as the number of processors increases.
- At the same time, it is impossible to obtain correct implementations of many important parallel algorithms without using the FETCH_AND_ADD operation.

Motivating Example

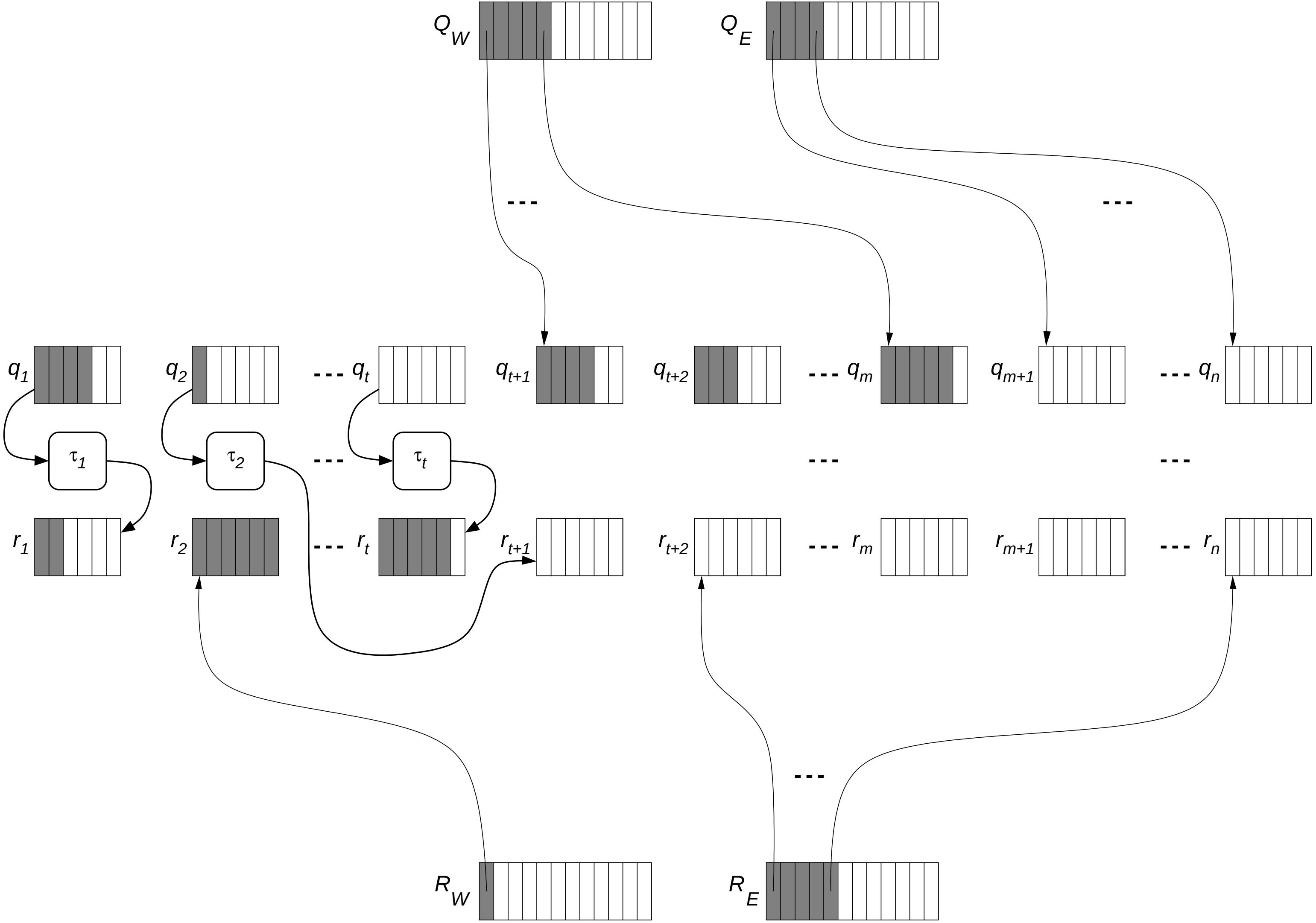
- Breadth First Search (BFS) will be used as a motivating example in the exposition of the SMPQ concept.
- BFS is a widely used operation at the heart of many graph algorithms and its efficient parallel implementation shall improve the performance of many existing and proposed parallel graph codes.
- However SMPQs are applicable directly, or with minor modification, to a much wider range of parallel algorithms.



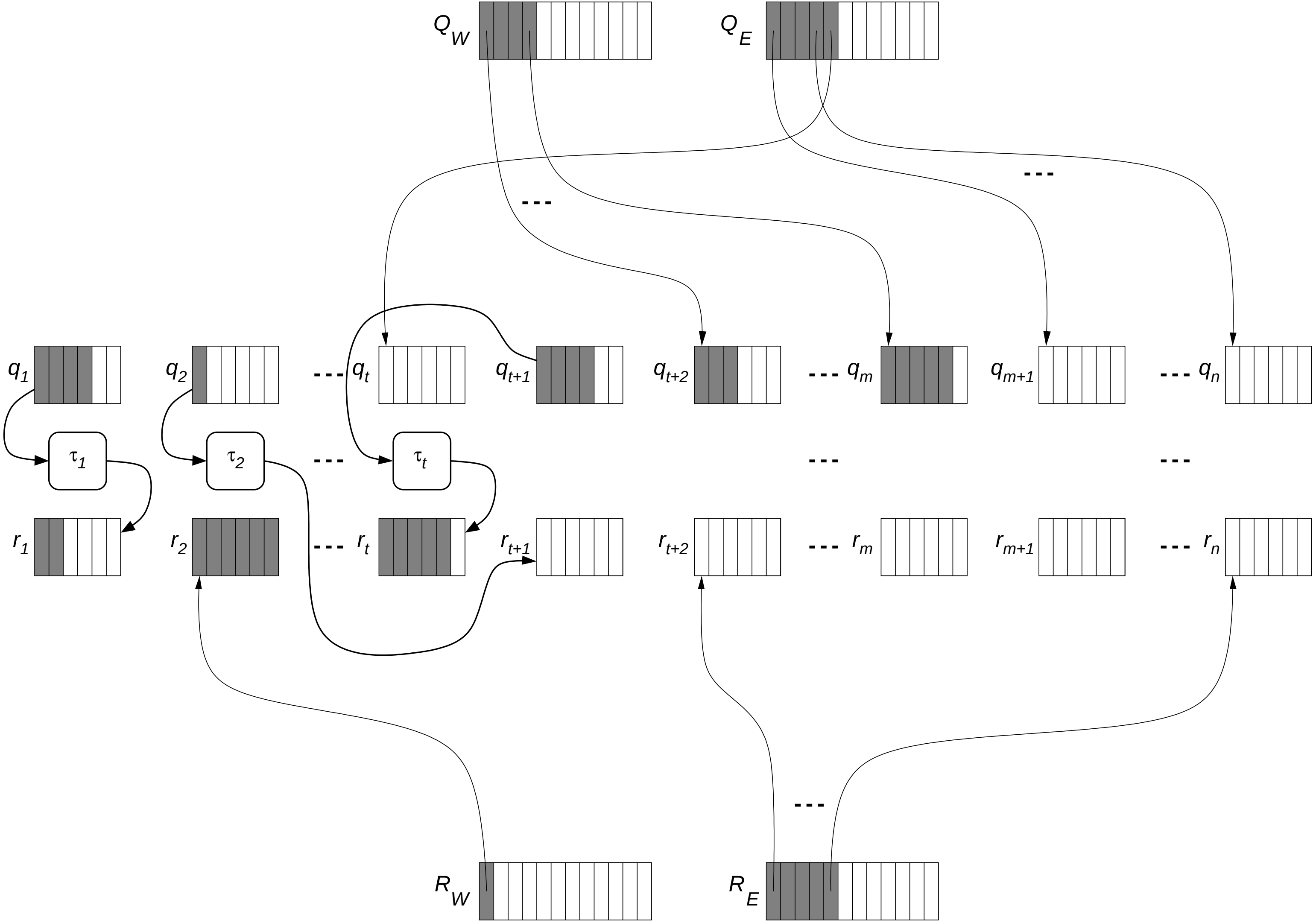
Two first level parallel queues Q_W/Q_E and R_W/R_E, each of size n, hold pointers to serial queues q_i and r_i respectively, each of size s. The total capacity of this system is $N = sn$. This figures shows an empty system, thus the pointers are in the queues of empty queues Q_E and R_E.



An intermediate stage in breadth first search (BFS). Each thread $\tau_i, 0 \leq i \leq t$ has acquired private input(output) queues $q_i(r_i)$ from $Q_W(R_E)$. A thread takes nodes from its private q and puts nodes on its private r. Q_W contains pointers to the remaining qs that are non-empty. $Q_E(R_E)$ contains pointers to the remaining qs(rs) that are empty. Thread τ_2 has just filled up its output



Thread $\boldsymbol{\tau_2}$ puts its filled queue $\boldsymbol{r_2}$ in $\boldsymbol{R_W}$ and gets a fresh output queue $\boldsymbol{r_{t+1}}$ from $\boldsymbol{R_E}$. At this point thread $\boldsymbol{\tau_t}$ has emptied out its input queue $\boldsymbol{q_t}$.


Q_W
Q_E
q_1
q_2
q_t
q_{t+1}
q_{t+2}
q_m
q_{m+1}
q_n
τ_1
τ_2
τ_t
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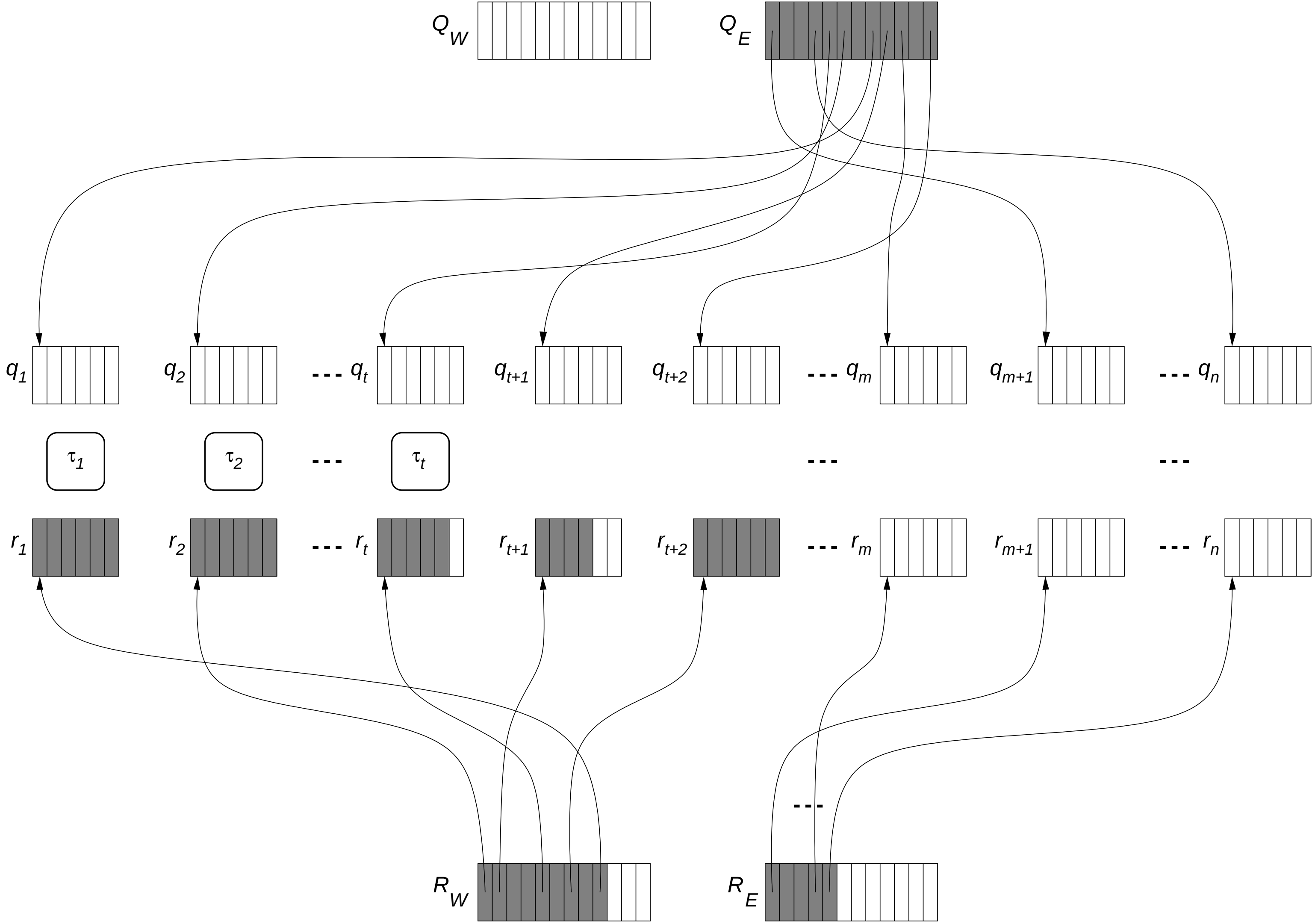
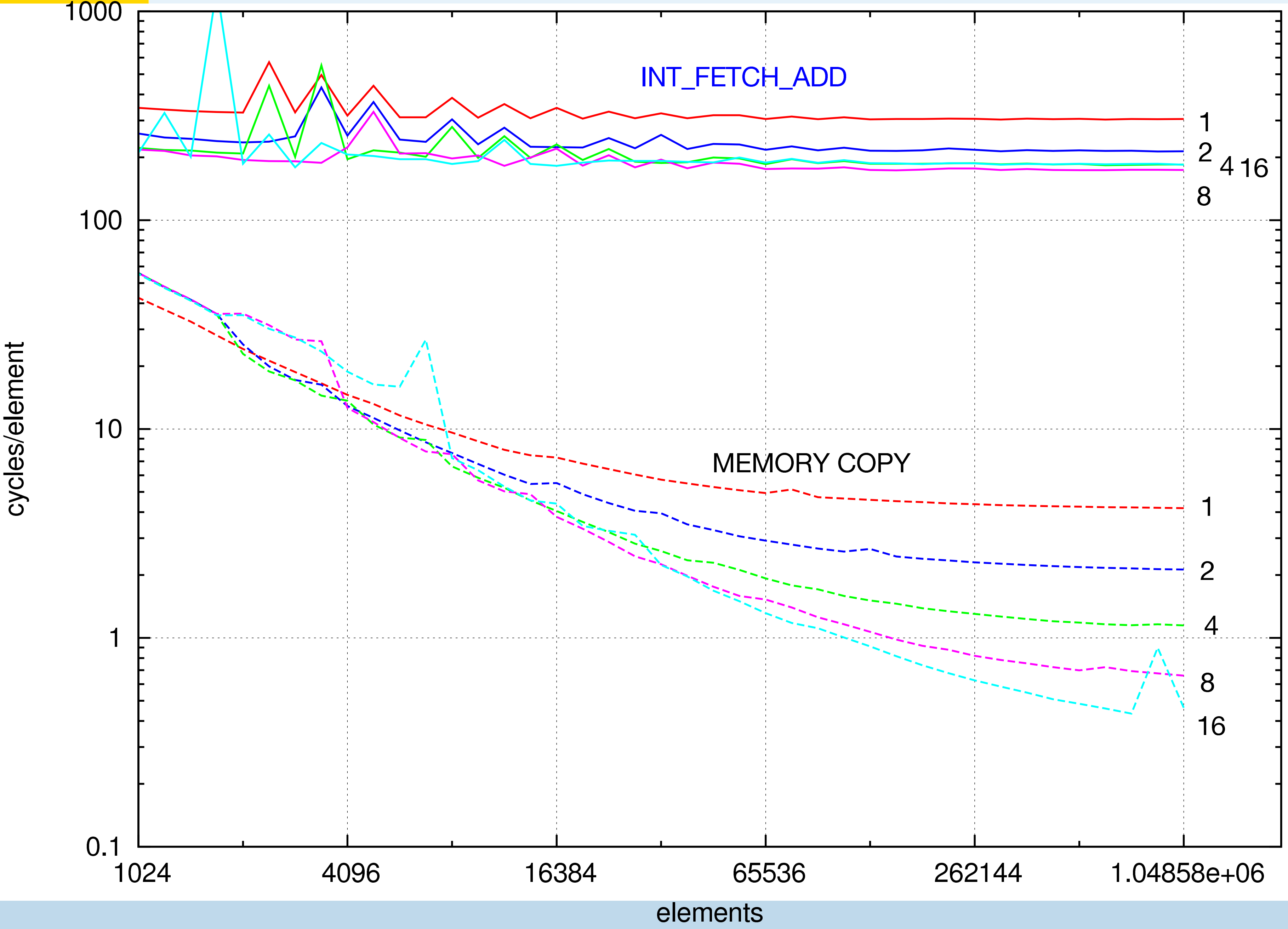
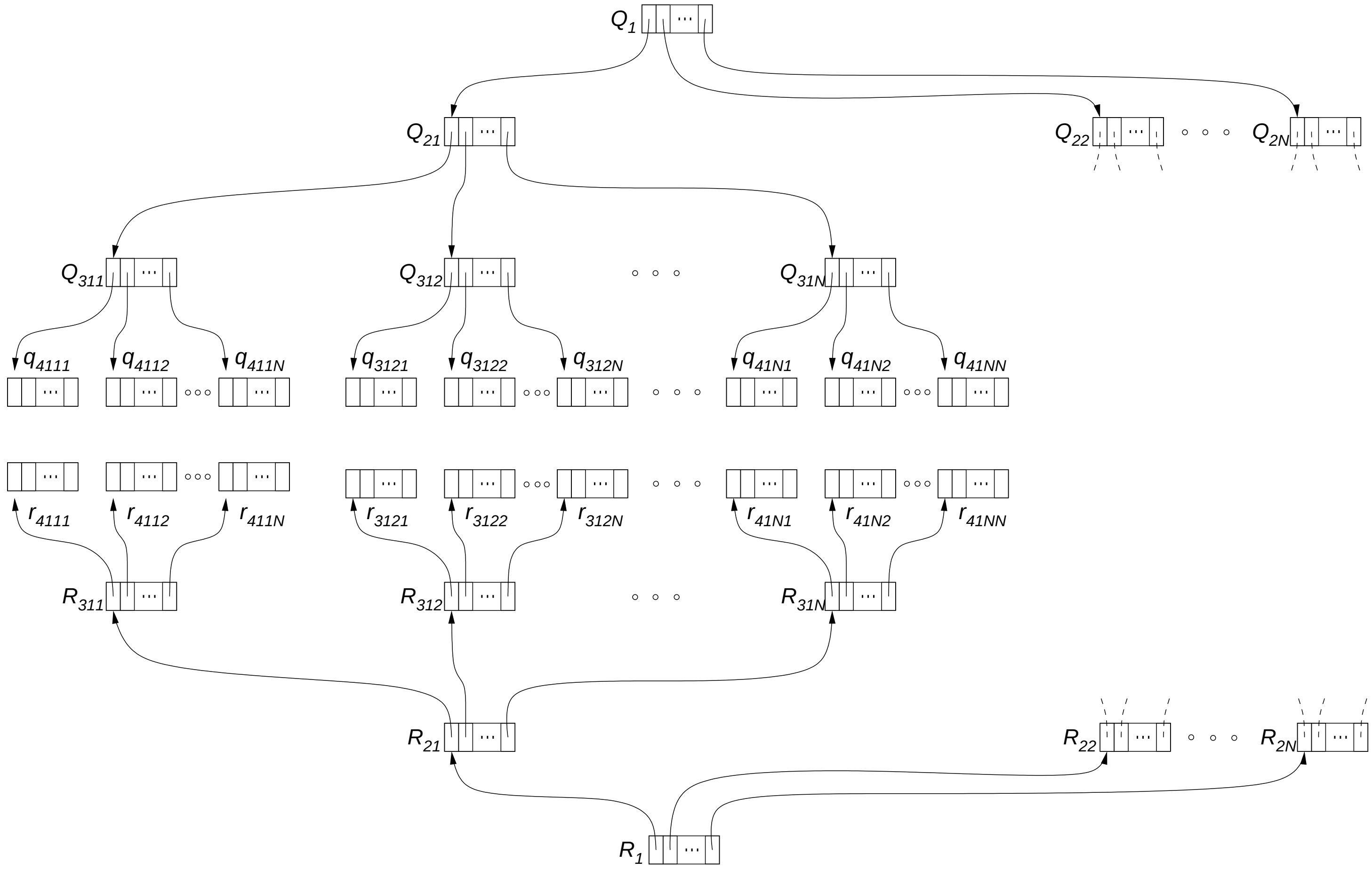


One stage of the BFS is completed, all input queues $\boldsymbol{q_i}$ (originally in $\boldsymbol{Q_W}$) have been emptied and put in $\boldsymbol{Q_E}$. All output queues have been filled (as much as possible) and put in $\boldsymbol{R_W}$. At this point the roles of $\boldsymbol{Q_W}/\boldsymbol{Q_E}$ and $\boldsymbol{R_W}/\boldsymbol{R_E}$ (as well as $\boldsymbol{q_i}$s and $\boldsymbol{r_i}$s) are interchanged and the next stage proceeds (the system returns to the configuration shown in first Fig.).

Performance Bounds



Generalization



A shared multilevel parallel queuing system with $k = 4$. The E and W queues have been lumped together for simplicity.

Extensions

- The shared multilevel parallel queuing mechanism described above has been motivated and presented in the context of Breadth First Search (BFS), where the required capacity of the queue is known *a priori* and is bounded by the total number of nodes in the graph.

- It is equally applicable to other computational problems where a bound on the total queue size is known. However, there may be cases where a bound on the total queue size is not known beforehand.

- In such cases it is straightforward to extend the approach so that when the system sees the total capacity approach exhaustion, it allocates additional queues (in dynamic memory) and inserts them appropriately in the data structure. The overhead of carrying out these allocations will be hidden by the activity of the active threads, of which there may be thousands or even millions in a massively multithreaded system.