Problem

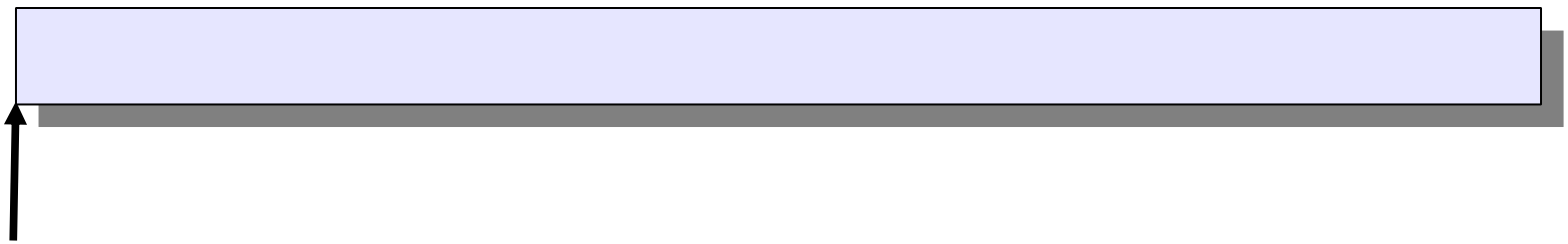
- Parallelize (serial) applications that use files.
  - Examples: compression tools, logging utilities, databases.
- In general
  - applications that use files depend on sequential output,
  - **serial append** is the usual file I/O operation.
- Goal:
  - perform file I/O operations in parallel,
  - keep the sequential, serial append of the file.

Results

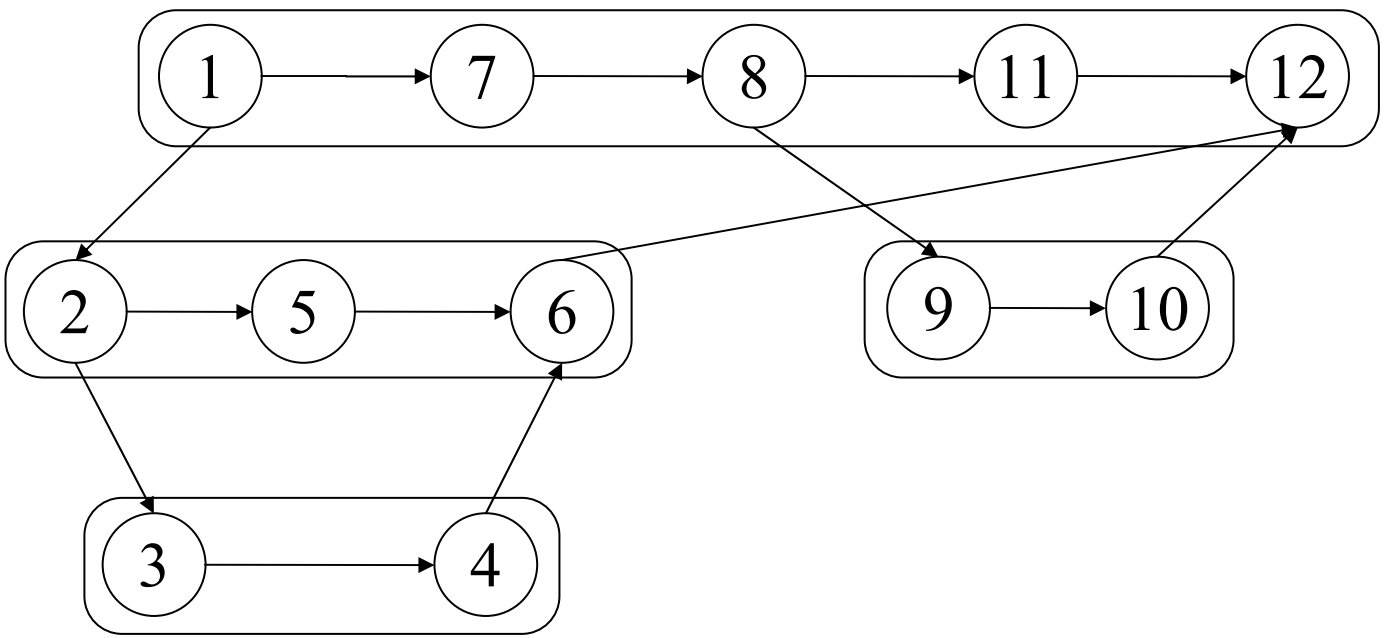
- *Cilk* **runtime-support** for serial append with good scalability.
- Three **serial append** schemes and implementations for *Cilk*:
  1. ported *Cheerio*, previous parallel file I/O API (*M. Debergalis*),
  2. simple prototype (with concurrent Linked Lists),
  3. extension, more efficient data structure (concurrent double-linked Skip Lists).
- Parallel bz2 using ***PLIO***.

Single Processor Serial Append

FILE (serial append)



computation DAG



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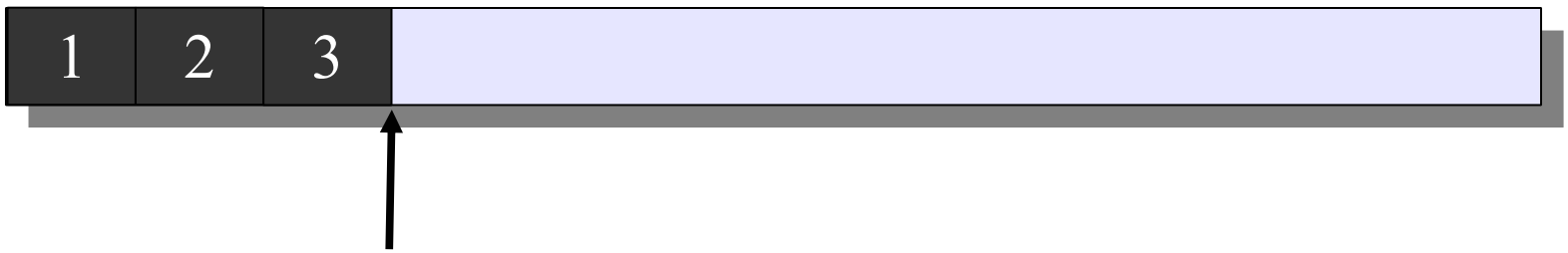

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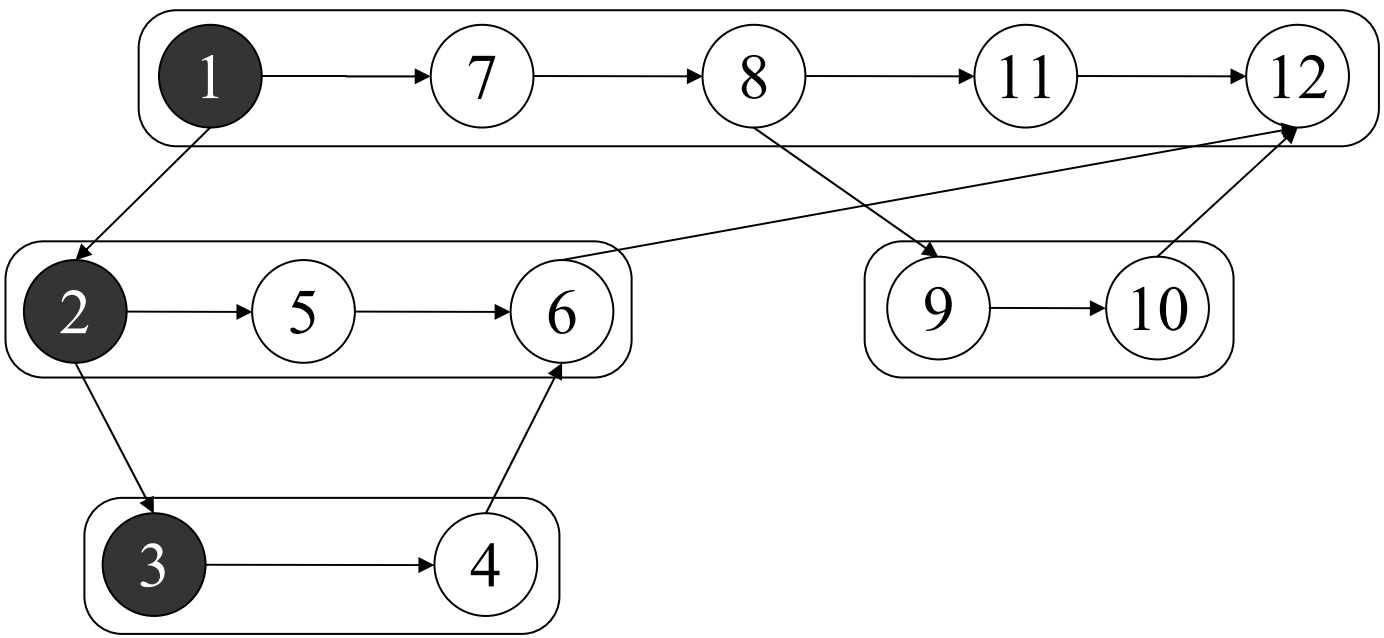

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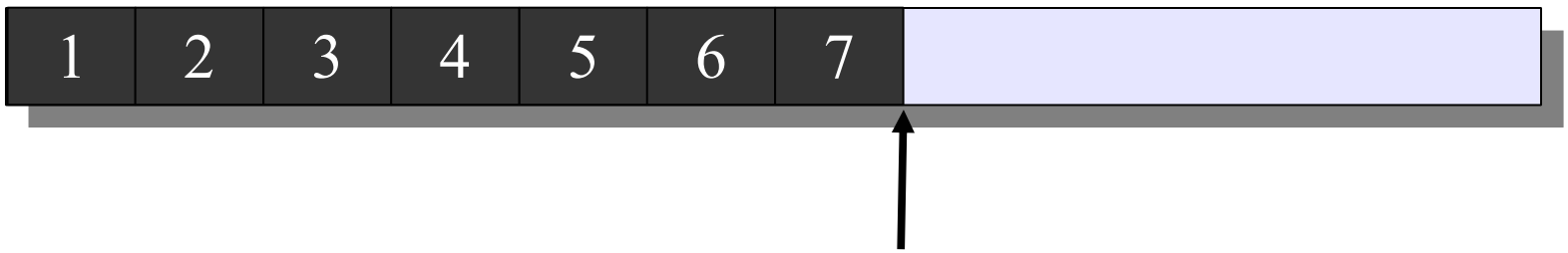

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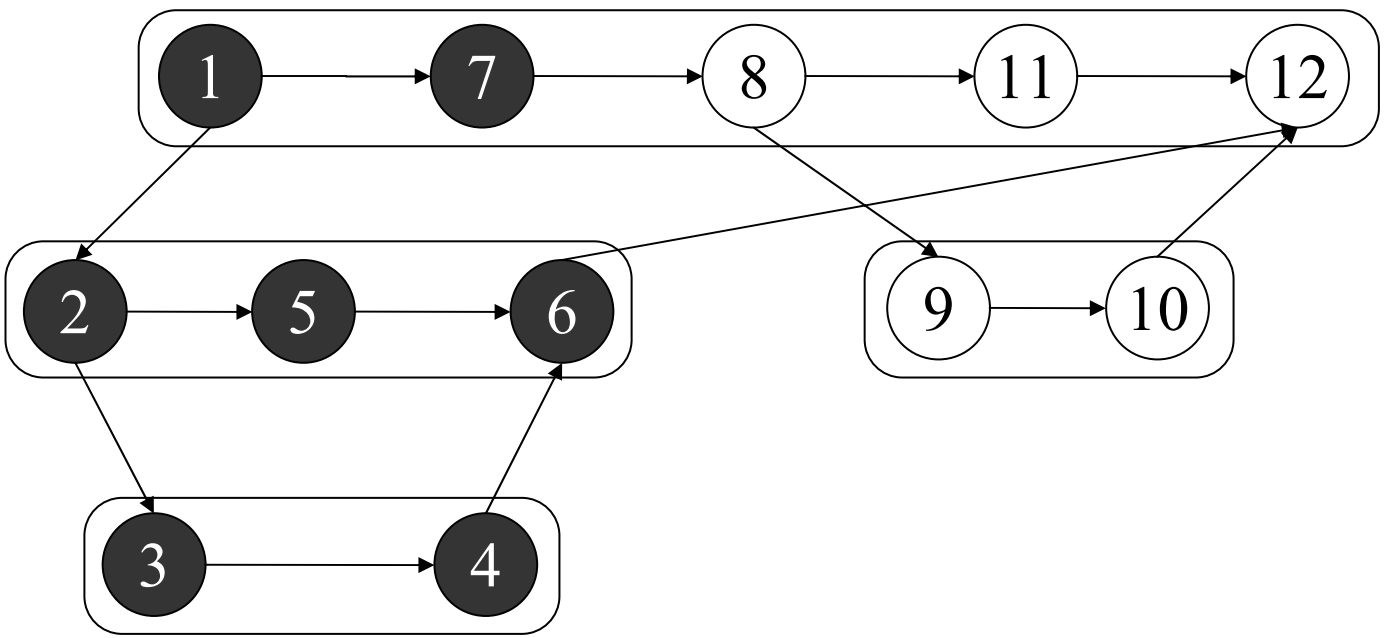

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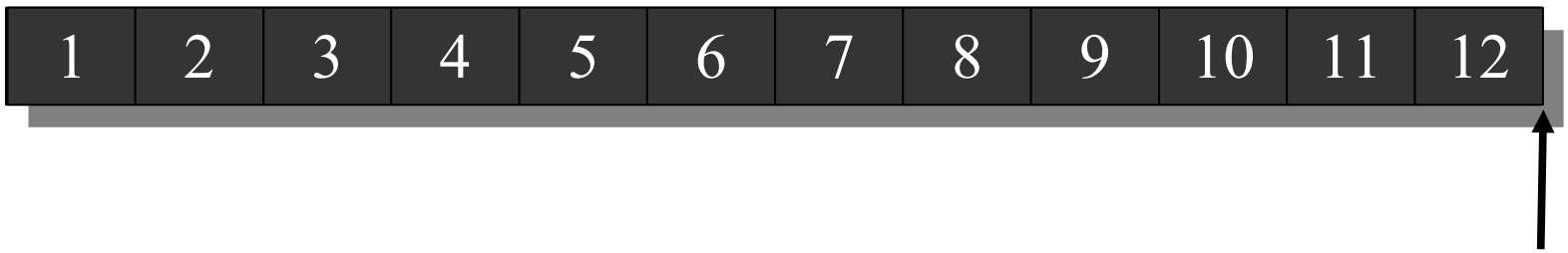

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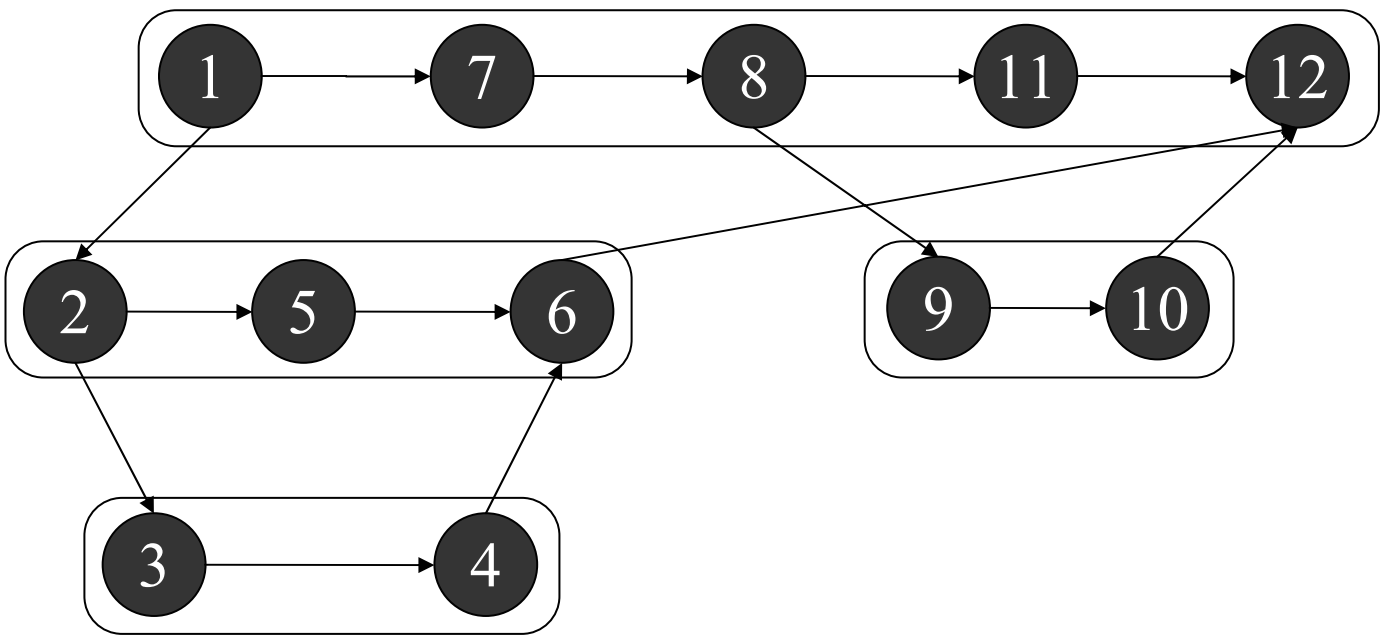

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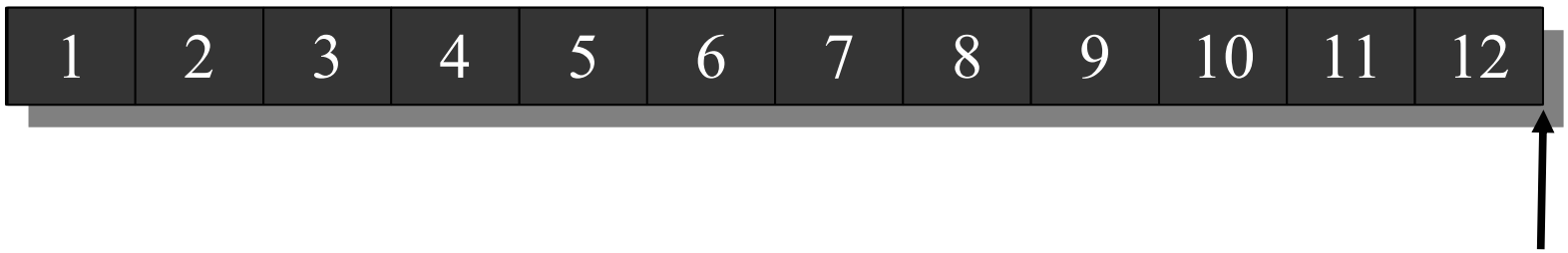
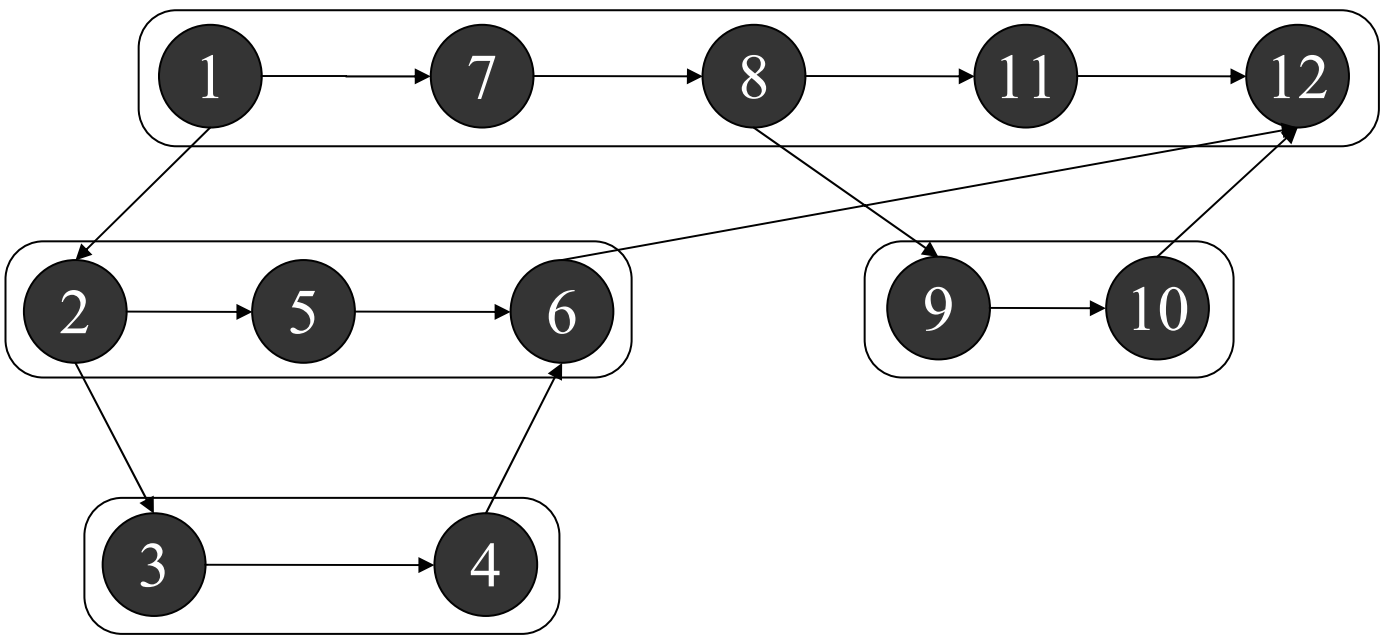


Why not in parallel?!

computation DAG



Fast Serial Append

Paralle**L** file **I/O** (**PLIO**) support
for Serial Append in
Cilk

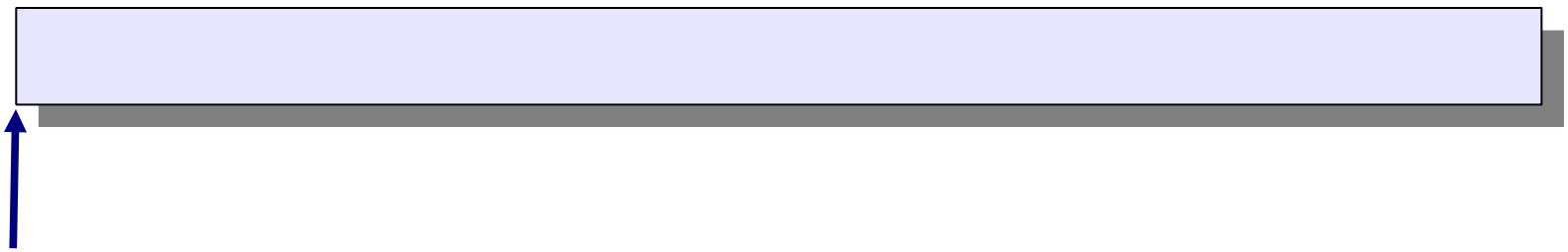
Alexandru Caracaş

Outline

- Example
  - single processor & multiprocessor
- Semantics
  - view of *Cilk* Programmer
- Algorithm
  - modification of *Cilk* runtime system
- Implementation
  - Previous work
- Performance
  - Comparison

Multiprocessor Serial Append

FILE (serial append)



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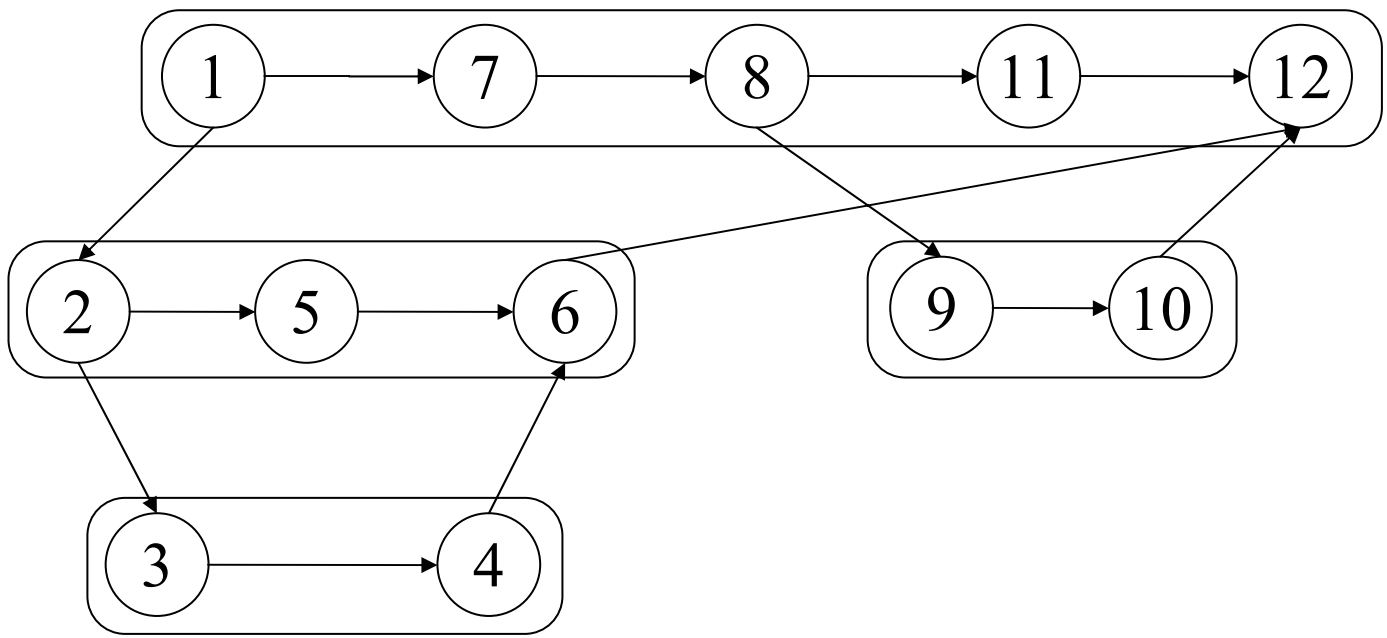

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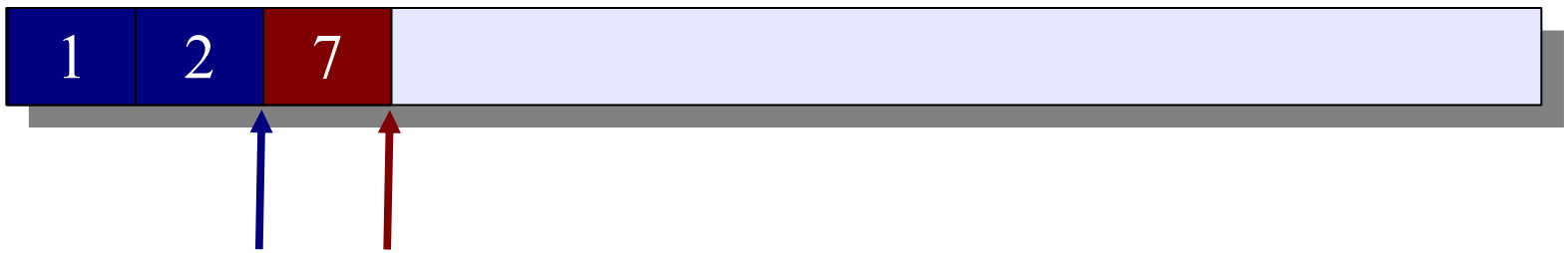

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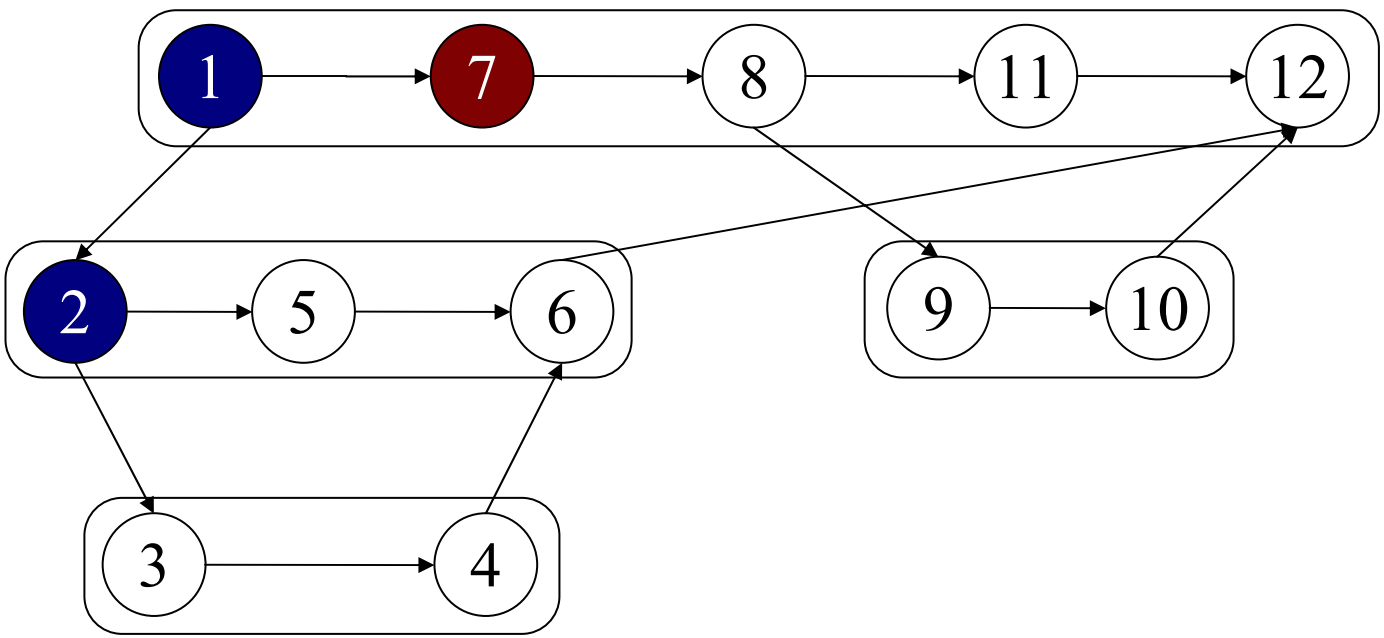

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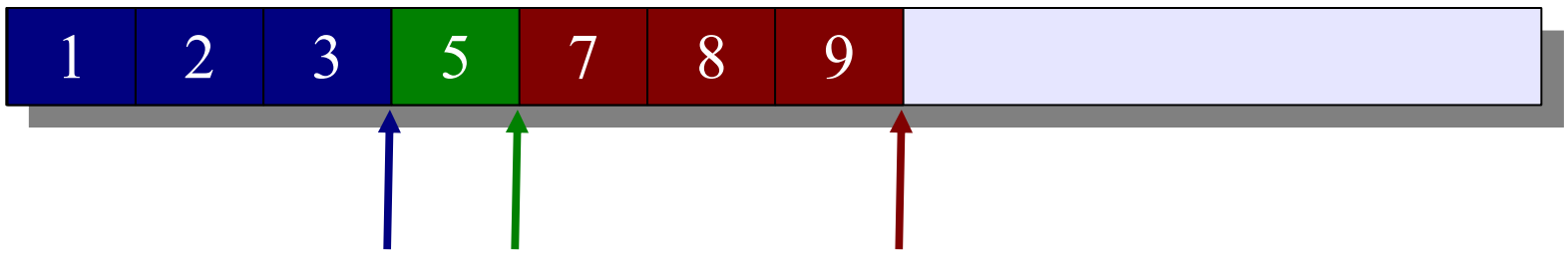

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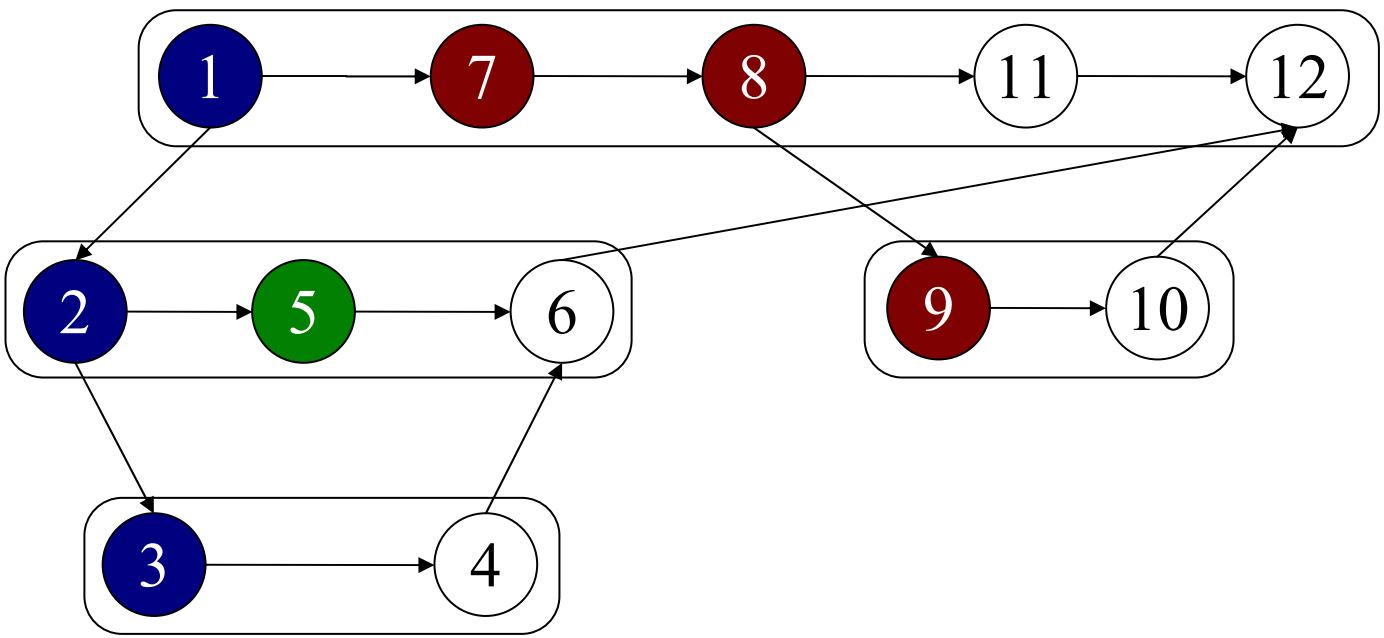

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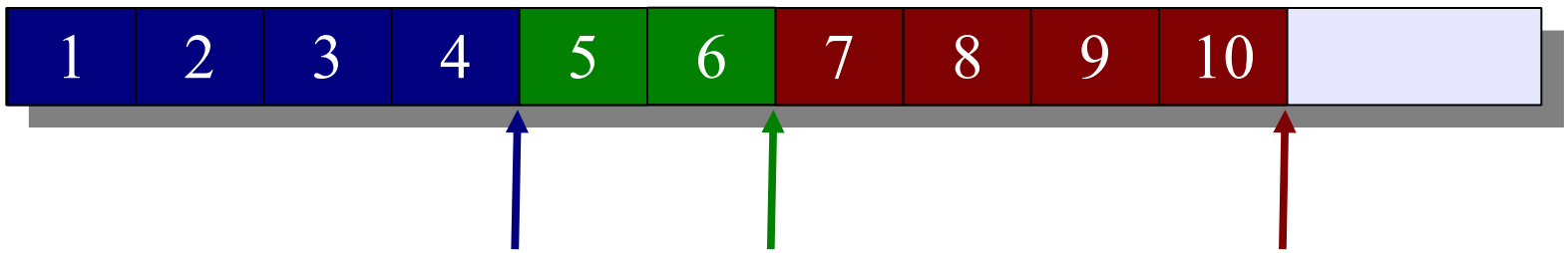

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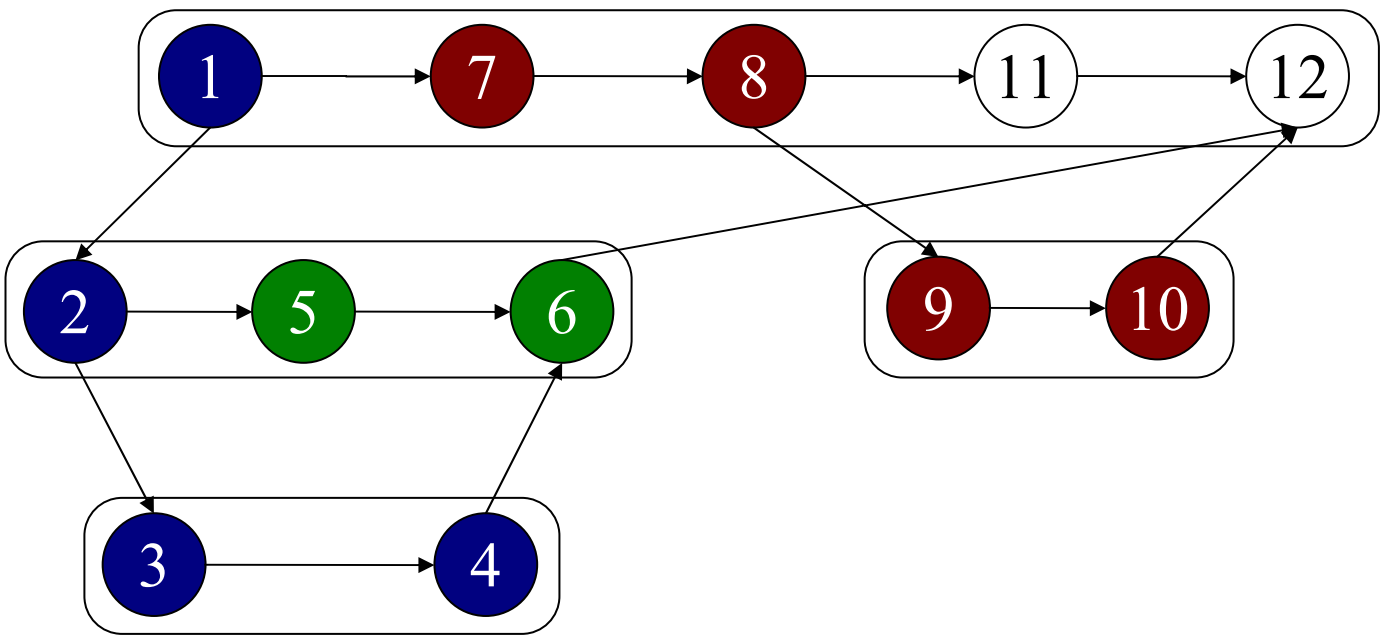

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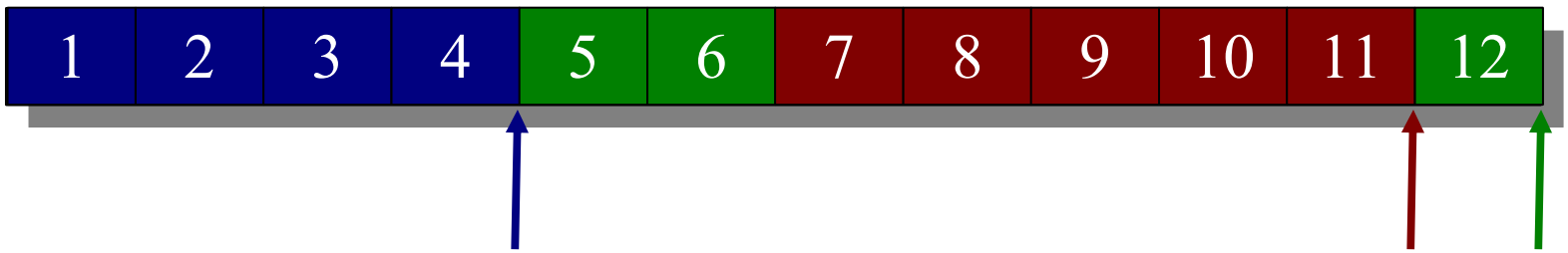

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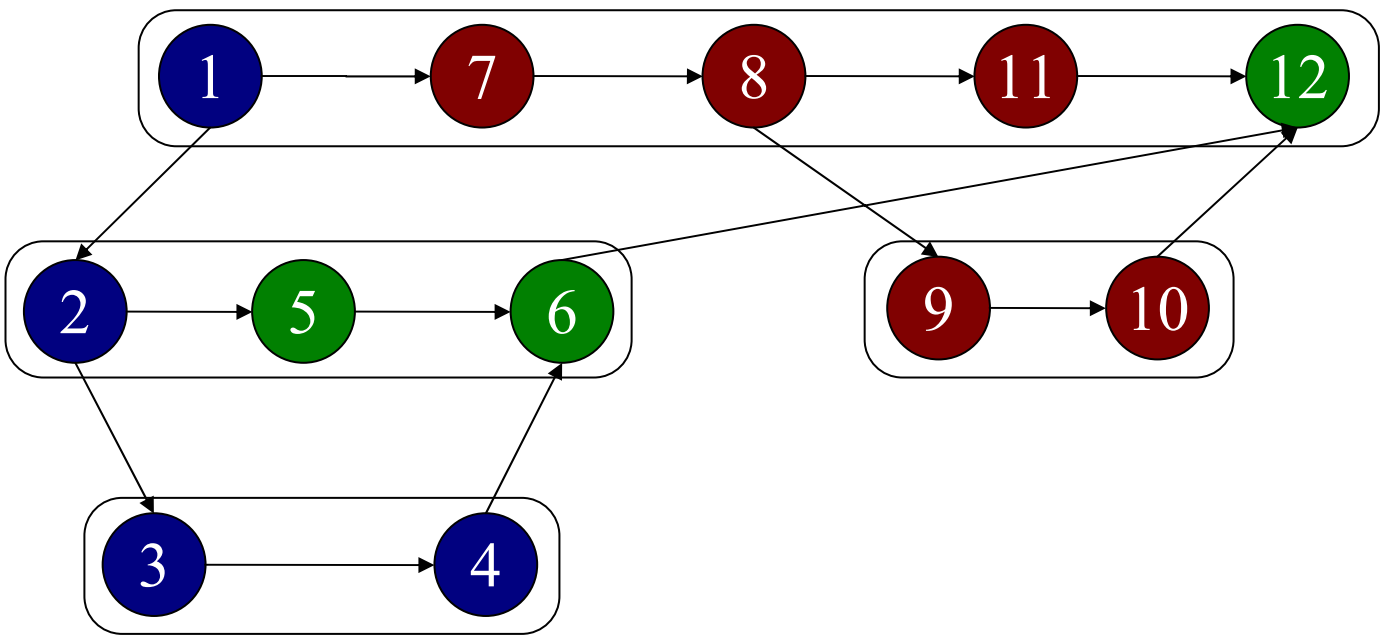


File Operations

- **open (FILE, mode) / close (FILE)**.
- **write (FILE, DATA, size)**
  - processor writes to its PION.
- **read (FILE, BUFFER, size)**
  - processor reads from PION.
    - Note: a seek operation may be required
- **seek (FILE, offset, whence)**
  - processor searches for the right PION in the ordered data structure

Semantics

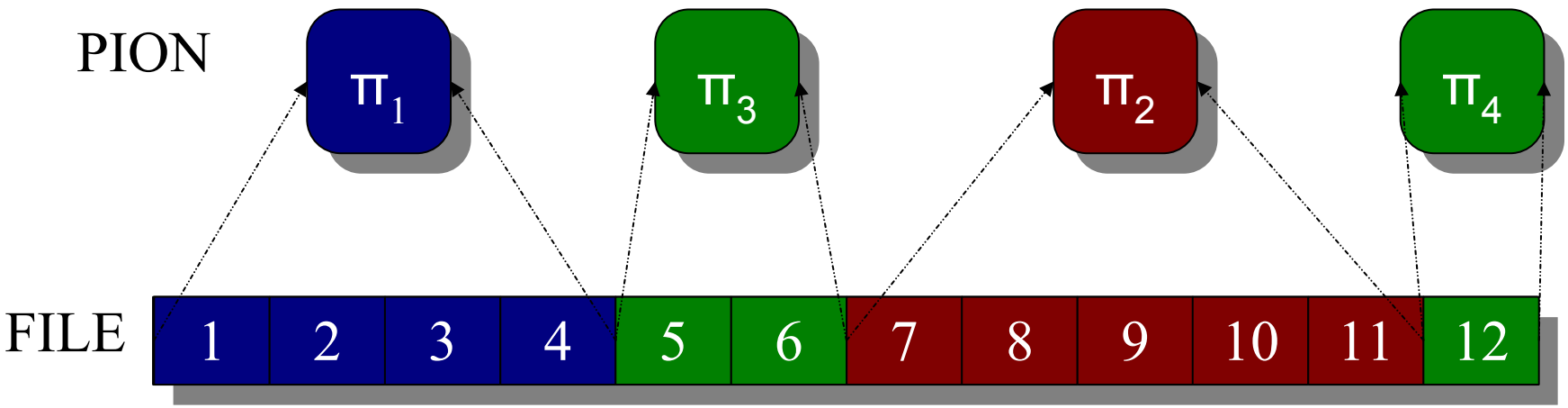
- View of *Cilk* programmer:
  - Write operations
    - preserve the sequential, serial append.
  - Read and Seek operations
    - can occur only after the file has been closed,
    - or on a newly opened file.

Approach (for *Cilk*)

- Bookkeeping (to reconstruct serial append)
  - Divide execution of the computation,
  - Meta-Data (PIONs) about the execution of the computation.
- Observation
  - In *Cilk,* **steals** need to be accounted for during execution.
- Theorem
  - expected # of steals = $O(PT_\infty)$.
- Corollary (see algorithm)
  - expected # of PIONs = $O(PT_\infty)$.

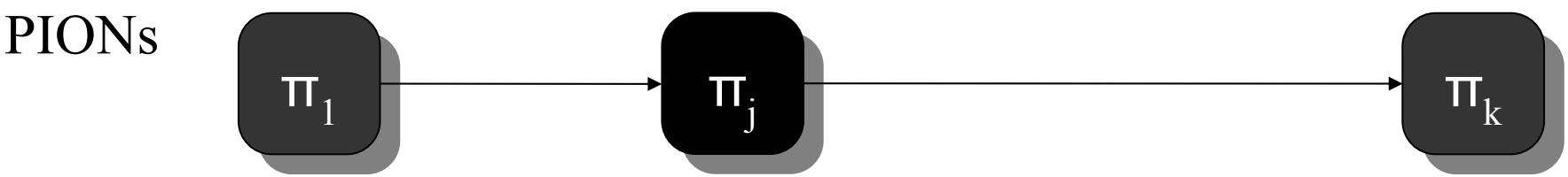
PION (**P**arallel **I/O** **N**ode)

- **Definition**: a PION represents all the write operations to a file performed by a processor in between 2 steals.
- A PION contains:
  - # data bytes written,
  - victim processor ID,
  - pointer to written data.



Algorithm

- All PIONSs are kept in an **ordered data structure**.
  - very simple Example: Linked List.
- On each steal operation performed by processor P_i from processor P_j:
  - create a new PION π_i,
  - attach π_i immediately after π_j, the PION of P_j in the order data structure.



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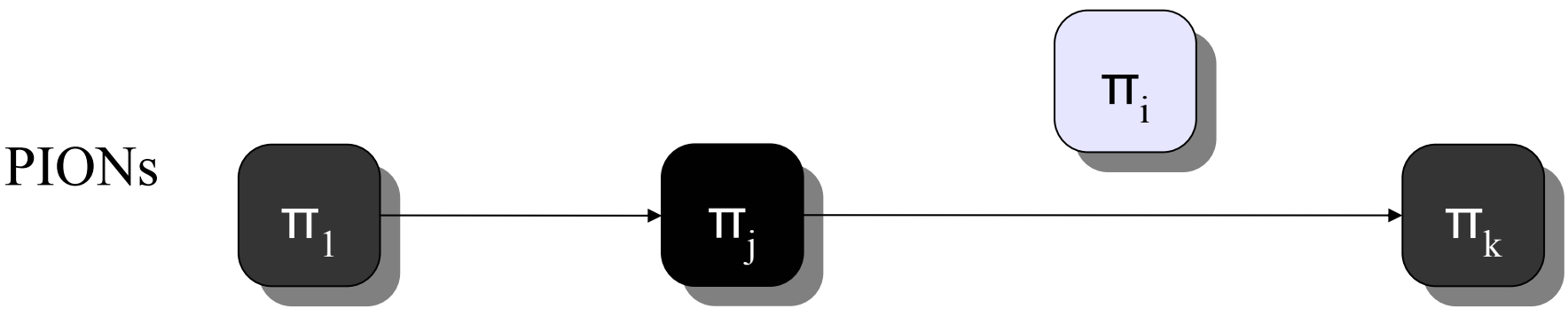

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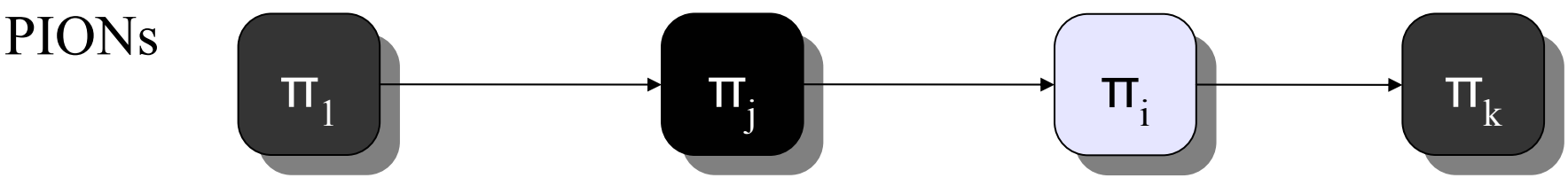


Implementation

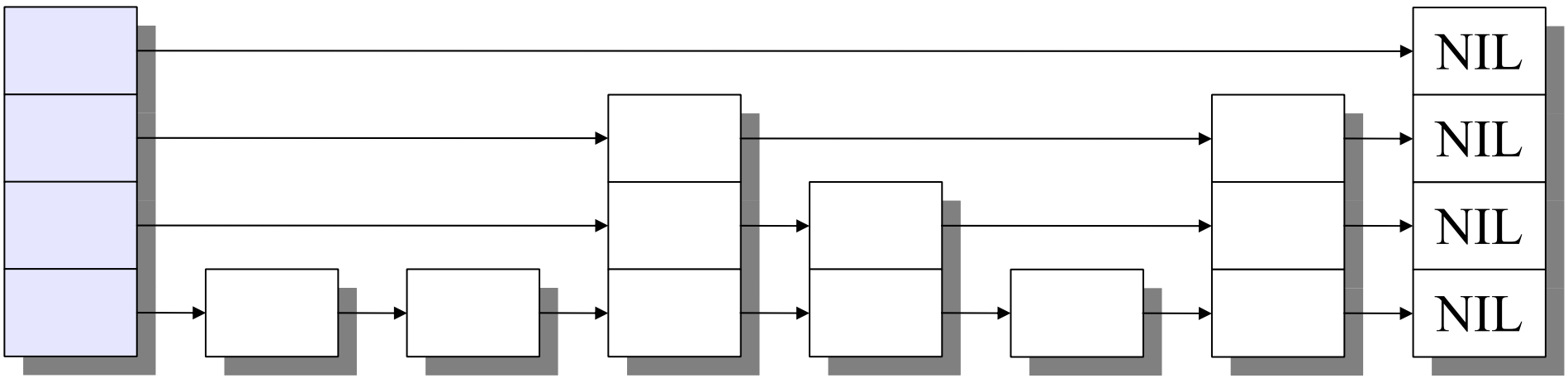
- Modified the *Cilk* **runtime system** to support desired operations.
  - implemented **hooks** on the steal operations.
- Initial implementation:
  - concurrent Linked List (easier algorithms).
- Final implementation:
  - concurrent double-linked Skip List.
- Ported *Cheerio* to *Cilk* 5.4.

Details of Implementation

- Each processor has a **buffer** for the data in its own PIONs
  - implemented as a file.
- Data structure to maintain the order of PIONs:
  - Linked List, **Skip List**.
- Meta-Data (order maintenance structure of PIONs)
  - kept in memory,
  - saved to a file when serial append file is closed.

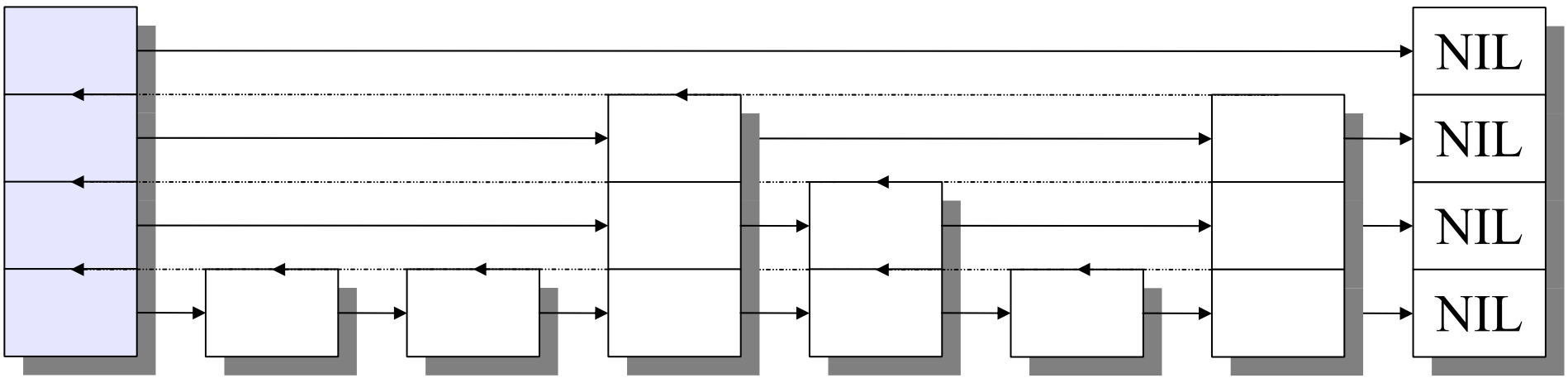
Skip List

- Similar performance with search trees:
  - O (log (SIZE)).



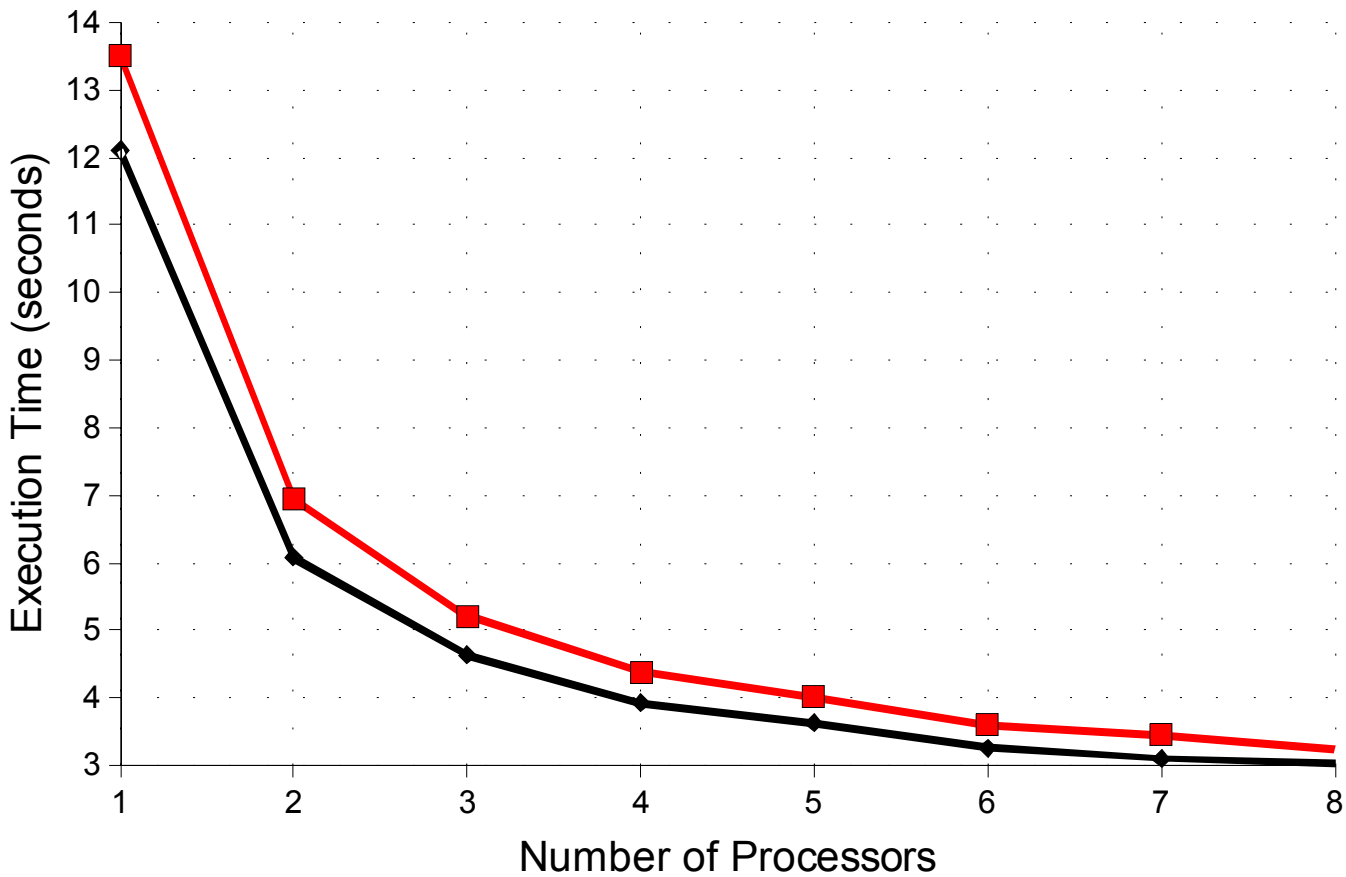
Double-Linked Skip List

- Based on Skip Lists (logarithmic performance).
- *Cilk* runtime-support in advanced implementation of PLIO as **rank order statistics**.



PLIO Performance

- no I/O *vs* writing 100MB with PLIO (w/ linked list),
- Tests were run on **yggdrasil** a 32 proc Origin machine.
- Parallelism=32,
- Legend:
  - black: no I/O,
  - red: PLIO.



Improvements & Conclusion

- Possible Improvements:
  - Optimization of algorithm:
    - delete PIONs with no data,
    - cache oblivious Skip List,
  - File system support,
  - Experiment with other order maintenance data structures:
    - B-Trees.
- Conclusion:
  - *Cilk* runtime-support for parallel I/O
    - allows serial applications dependent on sequential output to be parallelized.

References

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