Parallel Ray-Tracing with a Transactional DSM

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Distributed storage consistency

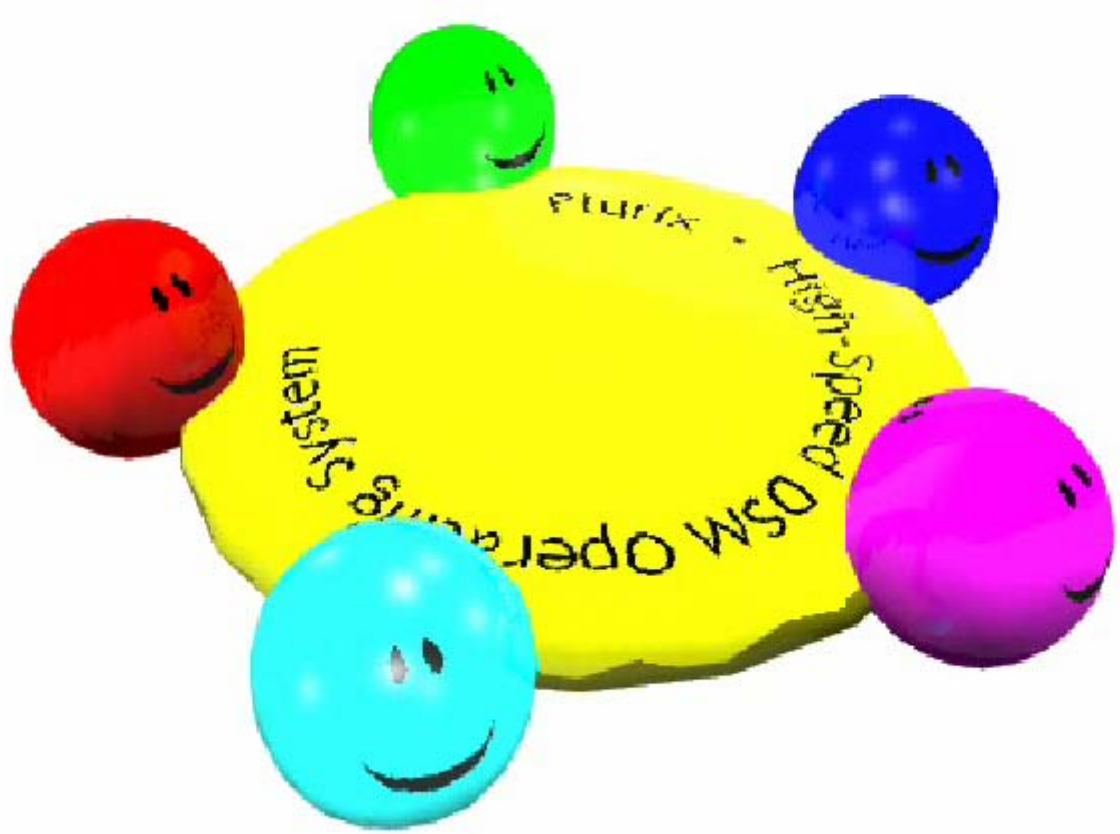
Restartable DSM transactions

Optimistic synchronization

Plurix DSM Architecture

Our ray tracing scenario

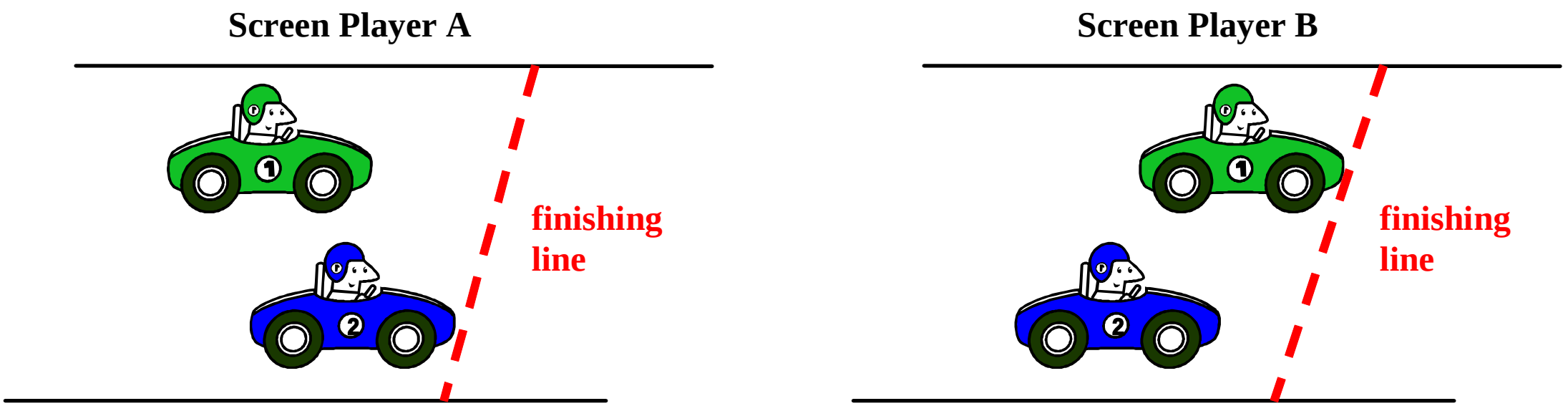
Cluster performance



Distributed storage consistency

- Coherence: How do processes see updates?
  - invalidate: a write operation invalidates all replicates on other nodes,
  - update: after a write operation all existing replicates are updated.

- Consistency: When do processes see updates?
  - contract between memory and processes.
  - All processes should have a common perspective on the distributed storage.
  - Example: multiplayer racing game → without consistency both players believe they are the winner.

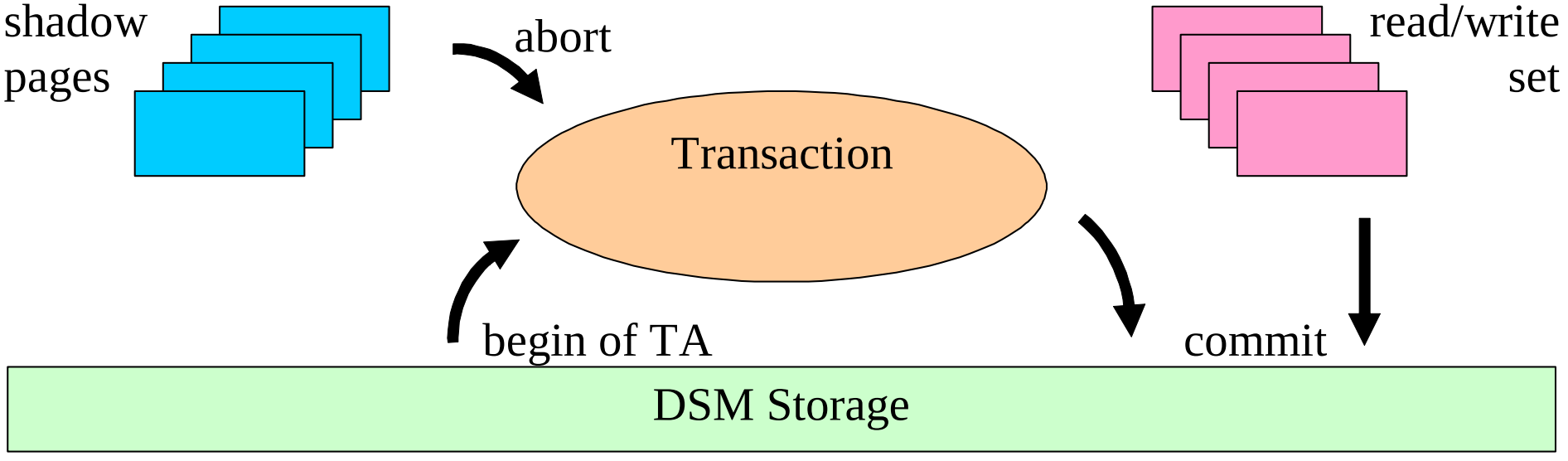


- Choosing a consistency model is always a trade off:
  - strong consistency is easy to program but less efficient,
  - weak consistency is more efficient but harder to program.

- Programmers must spend time for performance tuning of parallel programs:
  - improving concurrency and preserving correctness,
  - messages, locks, barriers, monitors, semaphores, begin/end-of-transaction …

Restartable DSM transactions

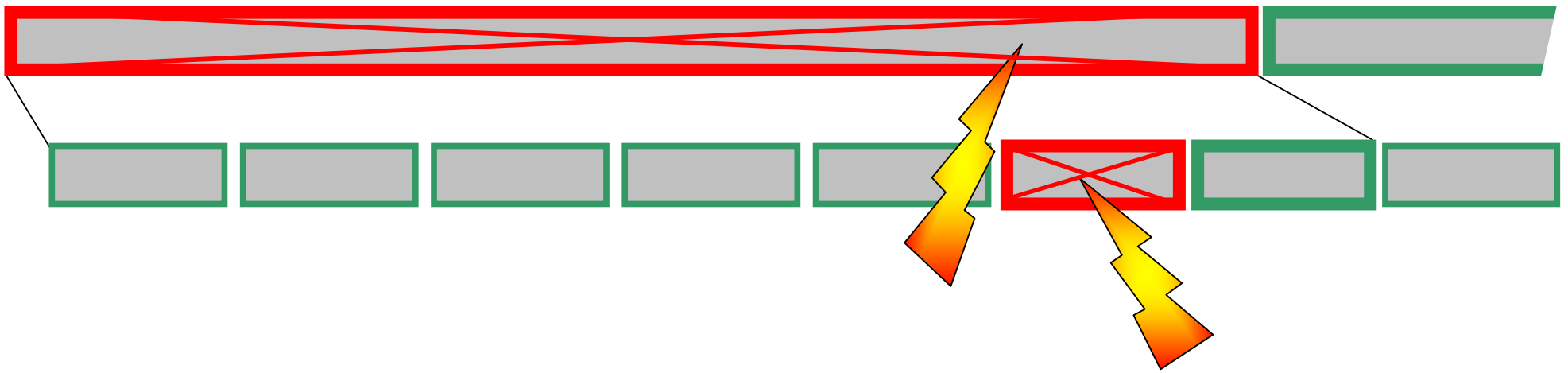
- Plurix Transactions observe the ACId principle:
  - Only after a successful commit of a transaction its modifications become visible to other stations.
  - When a transaction aborts all its modifications are undone → restartability.
- All computations are **implicitly** encapsulated into transactions.
- Read/write-sets are collected during the course of each transaction.
- The commit request broadcasts the write-set to all stations in the cluster.
- Stations will individually check whether they have to abort/restart the TA.
- Shadow copies of modified pages are created and restored when a TA aborts.



Optimistic synchronisation

- Assumption: read/write collisions between overlapping transactions are infrequent.
- Optimistic synchronisation lets the computation proceed and masks network latency.
- Traditional locks and barriers introduce network latency and the risk of deadlock.
- Short transactions reduce the probability of a collision.

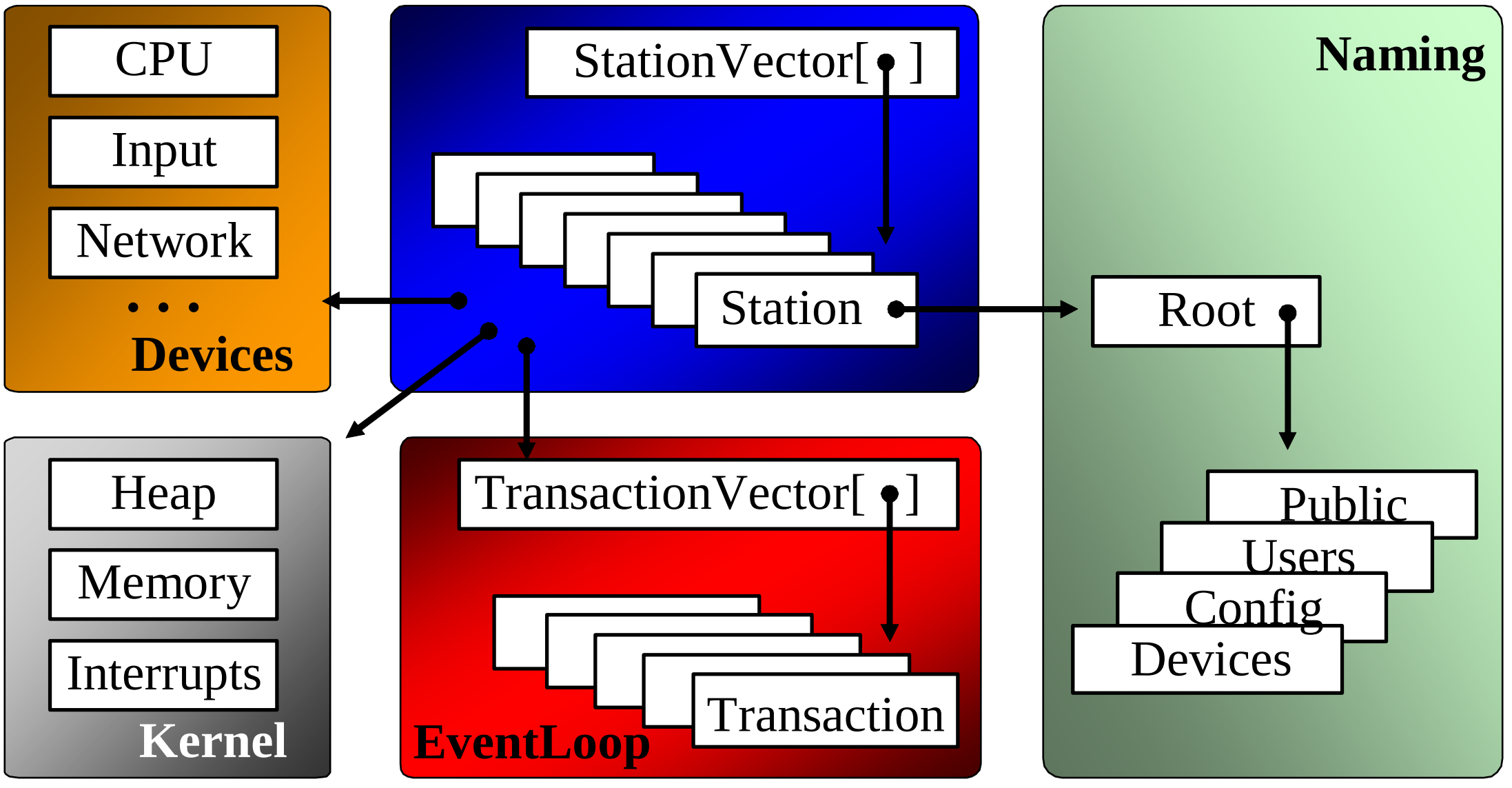
- To reduce collision cost long transactions may be **explicitly split** into smaller ones:
  - Integrated monitor facilities allow easy identification of critical hot spots.



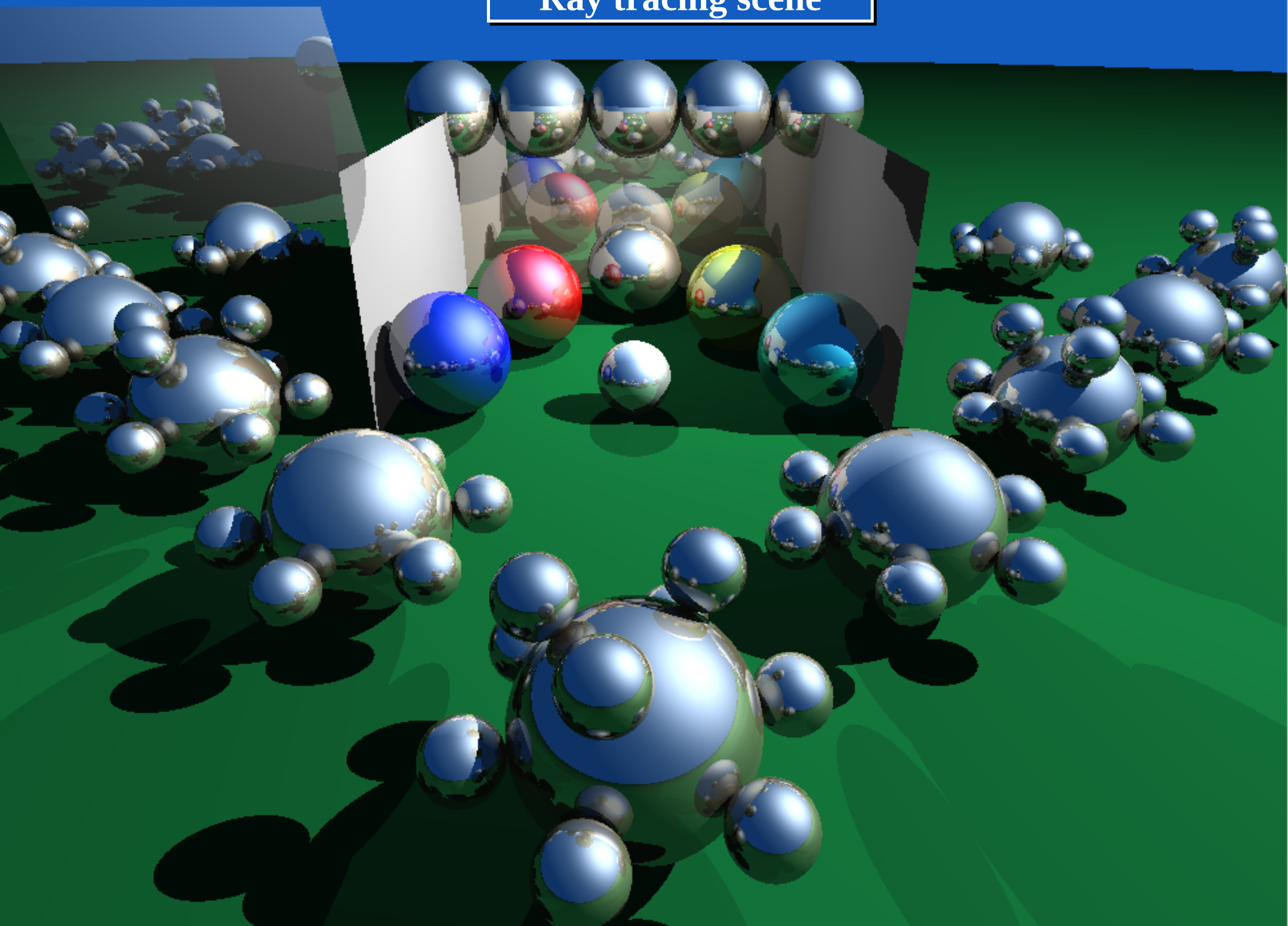
- Typical Plurix transactions are implicit and take much less than 1 second:
  - Entering a mouse click, a keystroke or a system command,
  - Compilation of a class or a program module,
  - Computation of a video frame ...

Architecture of the Plurix DSM system

- Sophisticated DSM memory management for PC clusters.
- Non-preemptive transaction loop in each station.
- Non-transactional interrupt & kernel space.
- Naming for persistent objects.
- Native Intel486 code.

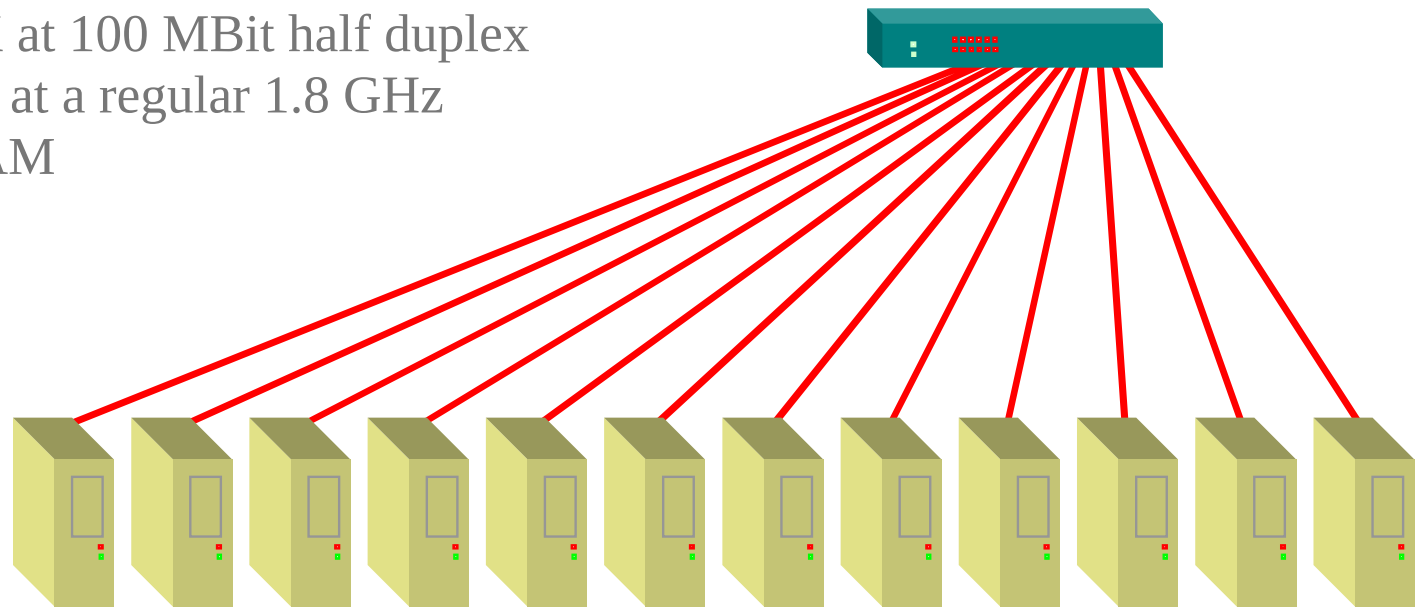


Ray tracing scene



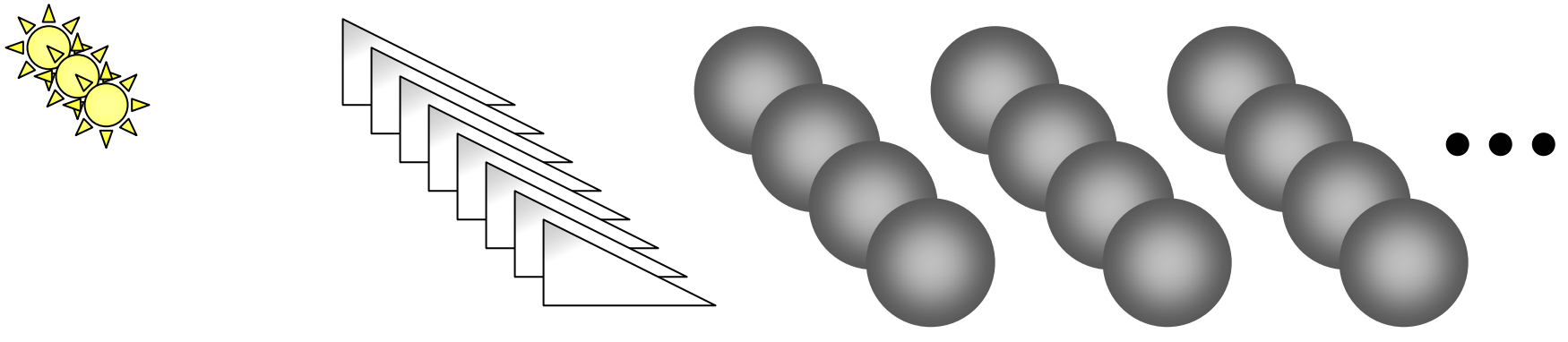
Cluster configuration

- **The Plurix PC cluster:**
  - Network adapter: 3com 905B-TX at 100 MBit half duplex
  - Main Processor: Athlon XP2500+ at a regular 1.8 GHz
  - Main memory: 512 MB DDR-RAM
  - Motherboard: Asus A7V8X-X
  - 12 nodes.



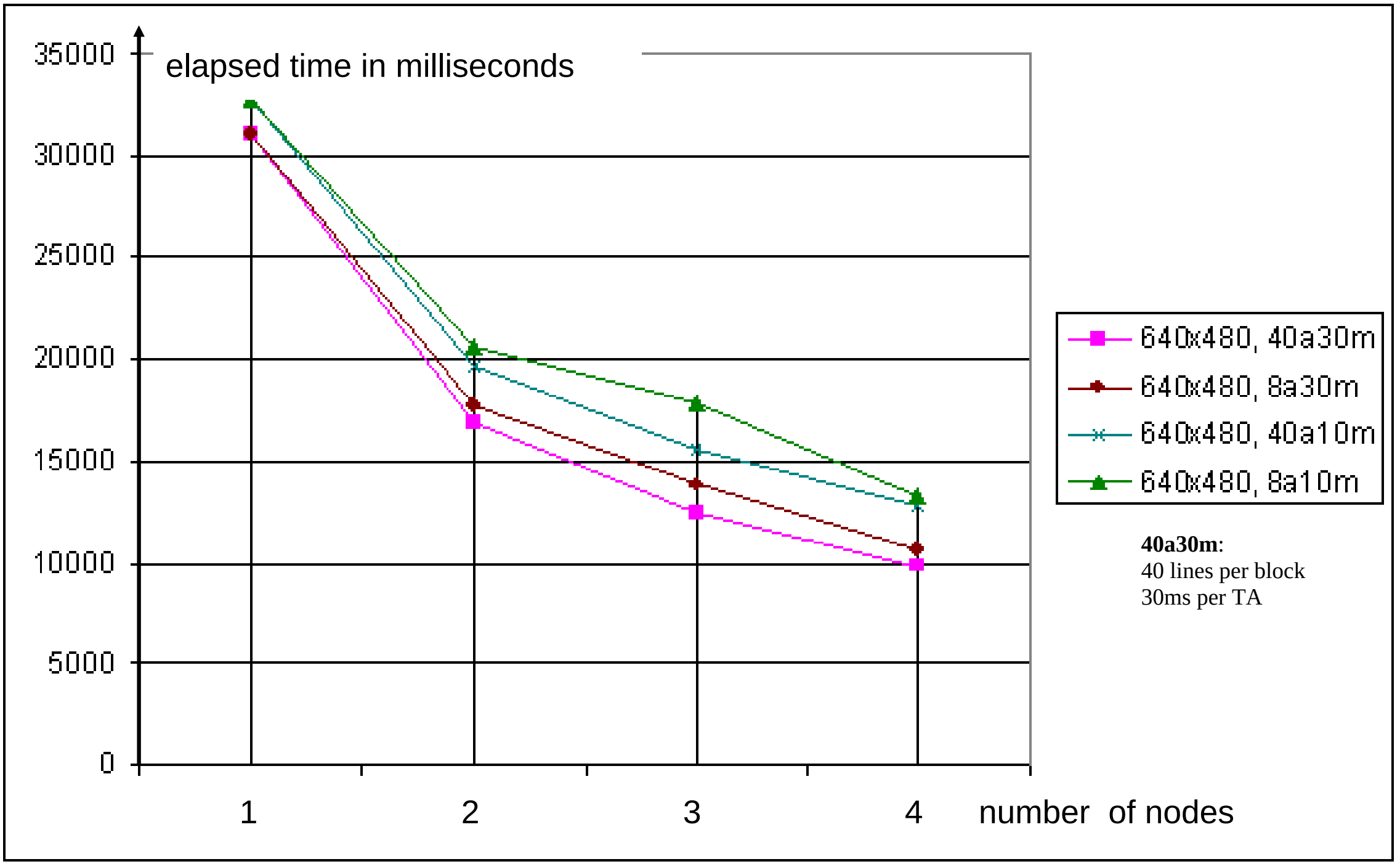
- **Ray Tracer:**
  - *m* lines per block,
  - *N* blocks per Image,
  - two phases:
    - o block allocation (short),
    - o pixel computation (longer),
  - all blocks are registered in the naming service,
  - adjustable transaction computation time interval,
  - faster nodes calculate more blocks as slower ones.

- **The test scene:** 3 light sources, 8 triangles, 104 reflecting spheres



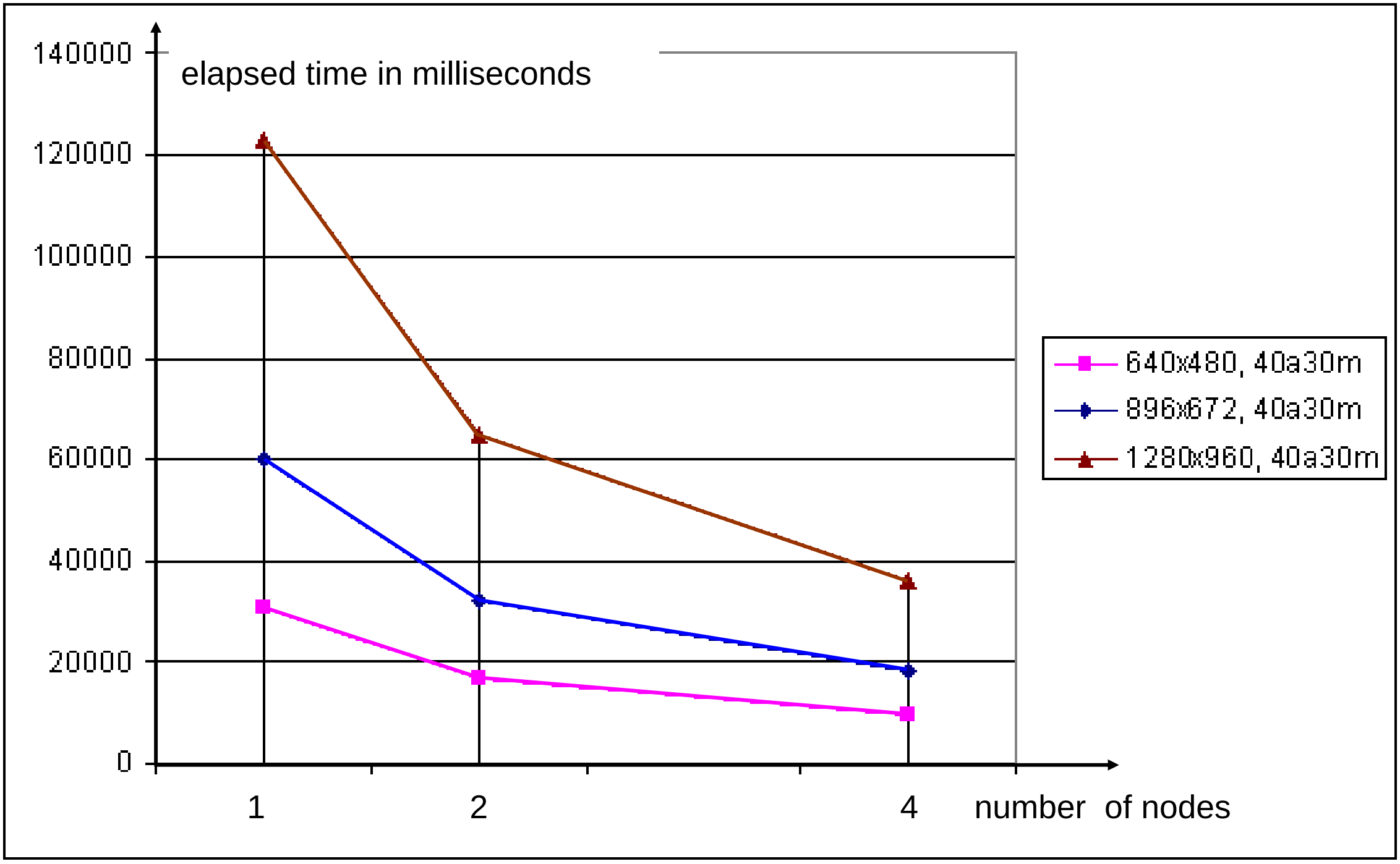
Computation time depending on blocksize and transaction time

- Larger blocksize for allocation of scanlines reduces collisions between stations.
- Longer transaction time reduces the overhead percentage (~ 300 µsec/TA).



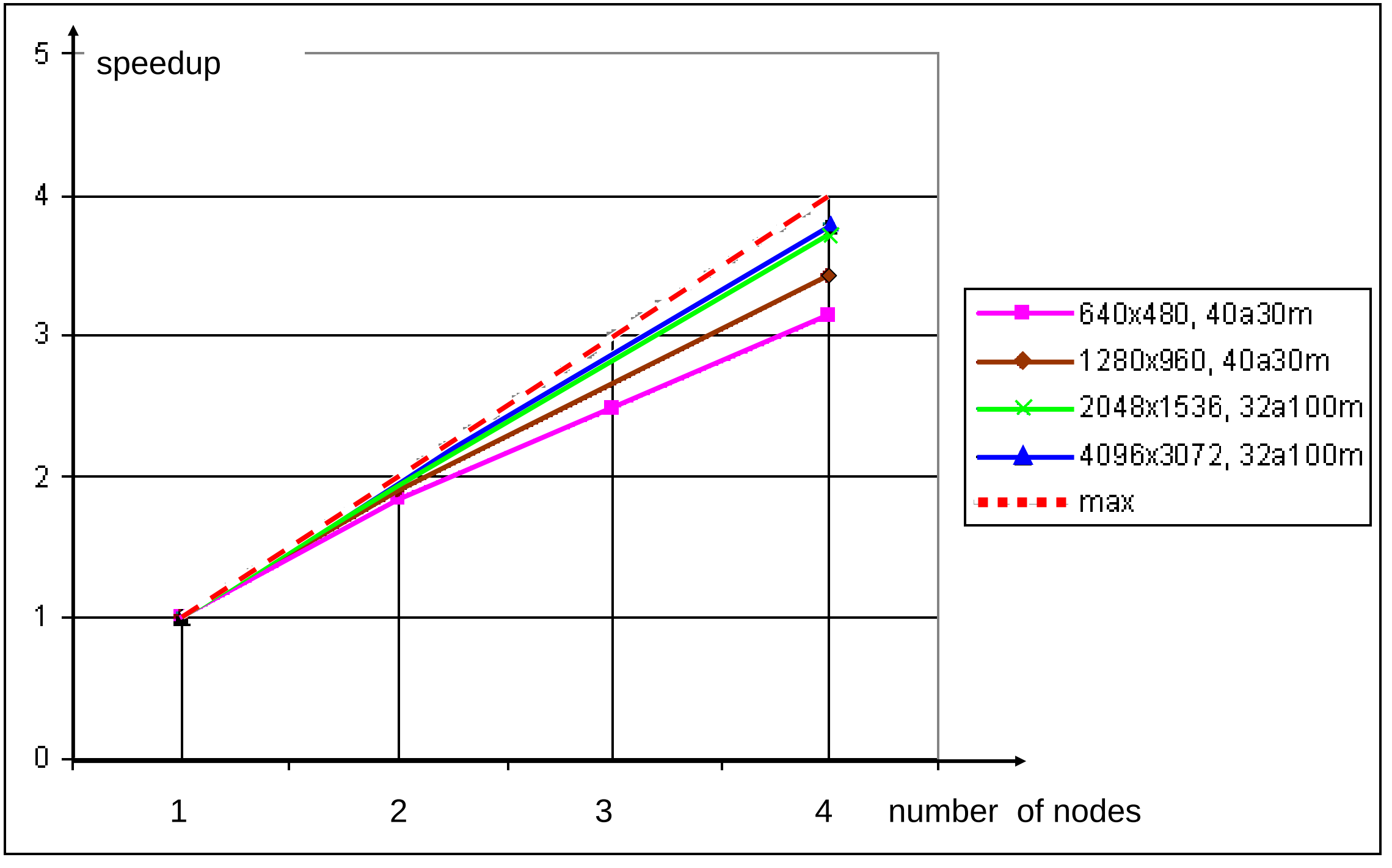
Computation time by number of nodes

- A single station still incurs transaction overhead but no paging and no collisions
- A single station takes approximately 3.5 times longer than 4 stations.
- Linear with number of pixels in the image.



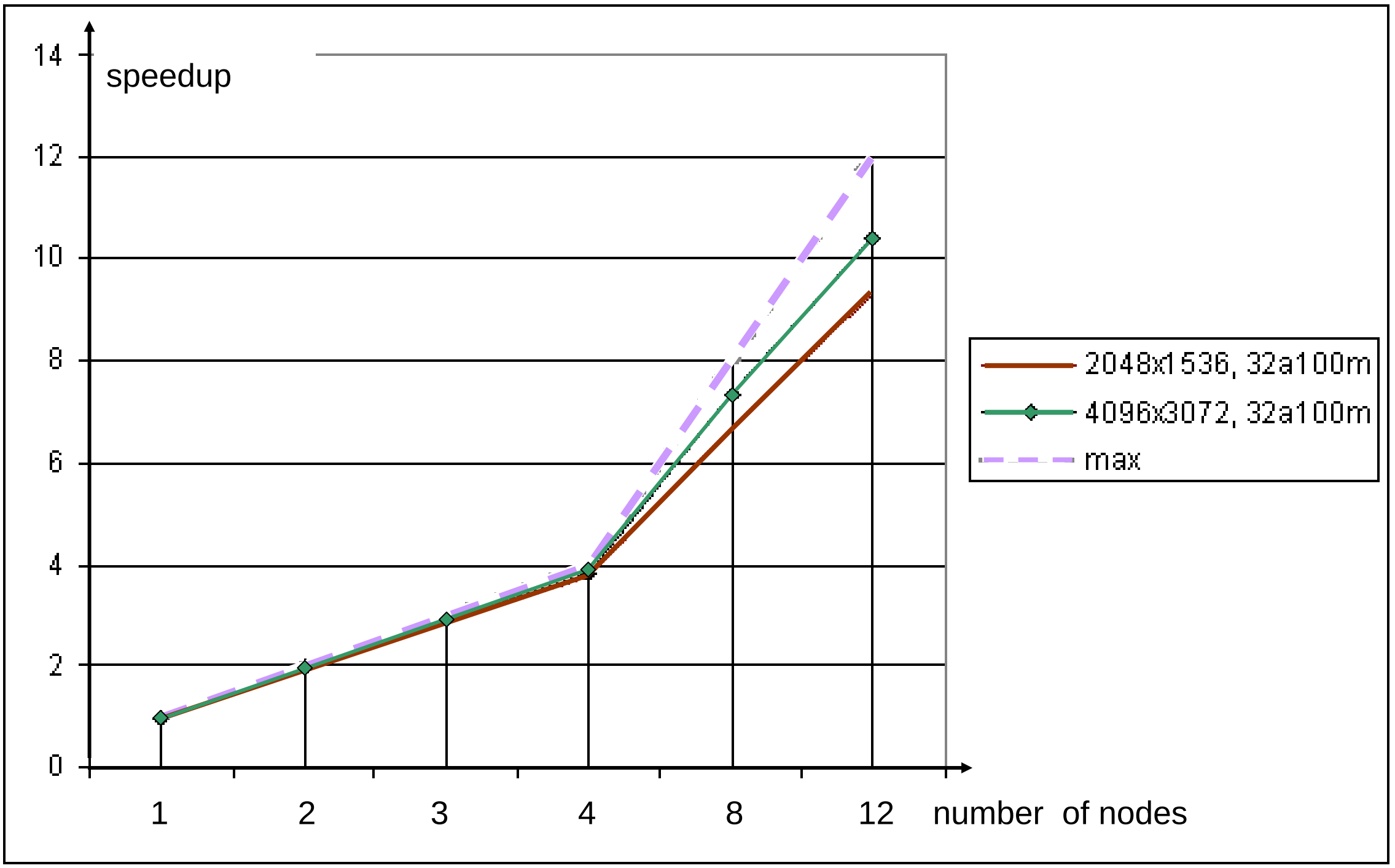
Speedup by number of nodes, varying resolution

- Large image sizes reduce the amount of collisions.
- Collisions are more severe with many cluster stations.



Computational speed-up

- Measured with up to 12 nodes.
- Good scalability for medium sized images (75% of max. speedup).
- Very good scalability for large size images (85% of max. speedup).



Conclusion

- A transactional DSM is an alternative to message passing application frameworks.
- It provides strong consistency for all shared objects in the cluster.
- Synchronising sets of state changes (transactions) is efficient.
- It simplifies the development of distributed applications.
- **It lends itself to lean & reliable implementation =>**
- Correctness of the algorithm is easily achievable.
- Concurrent performance requires tuning.
- Access patterns require special care.