Transactional Memory Evaluation using Apache Webserver

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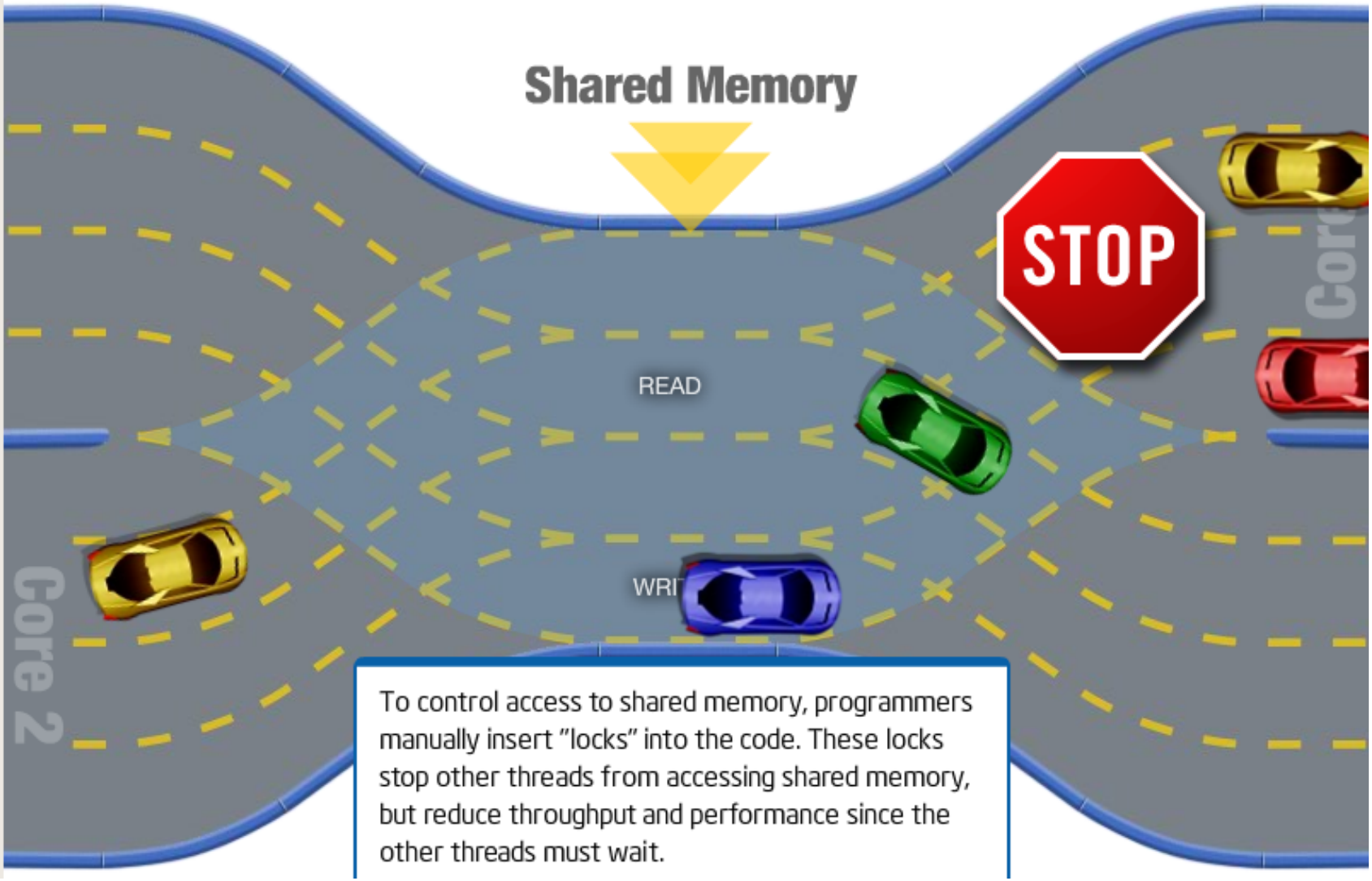
Traditional Synchronization

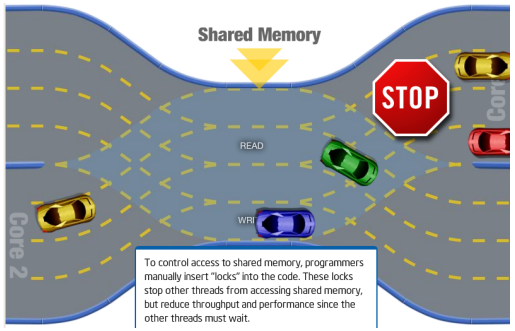
Example

```
void withdraw(account, amount) {
  accounts[account] -= amount;
}
```

Course-Grained Locks



Course-Grained Locks

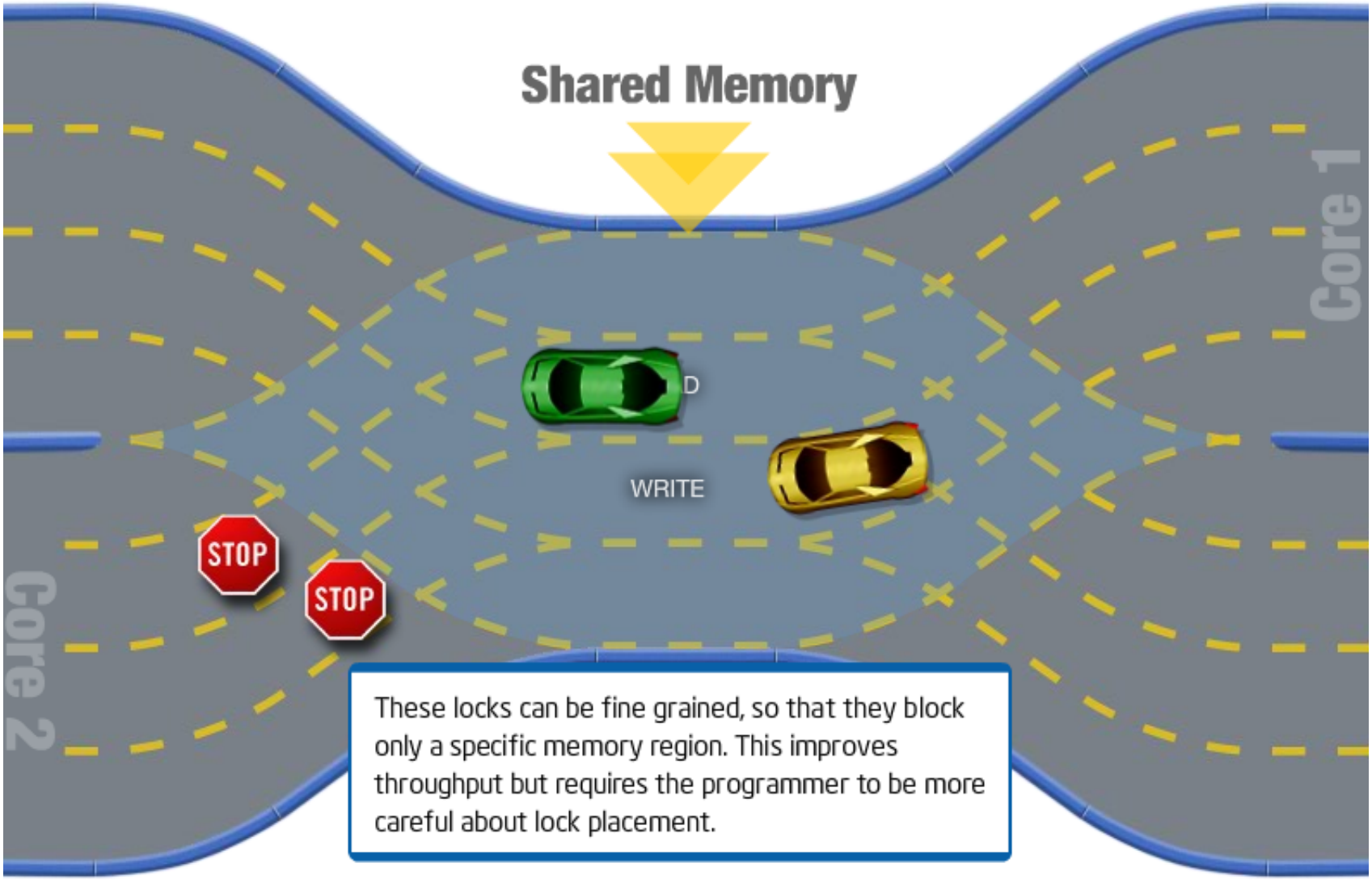


Example

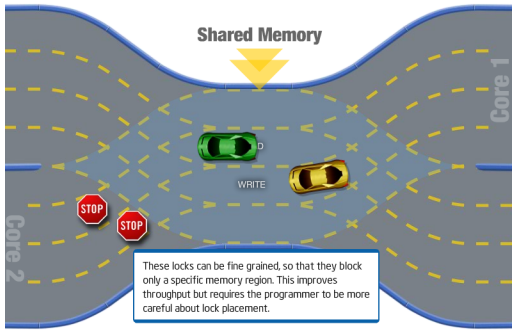
```
void withdraw(account, amount) {
  lock(big_mutex);
  accounts[account] -= amount;
  release(big_mutex);
}
```

- Easy to program.
- Doesn't scale.

Fine-Grained Locks



Fine-Grained Locks

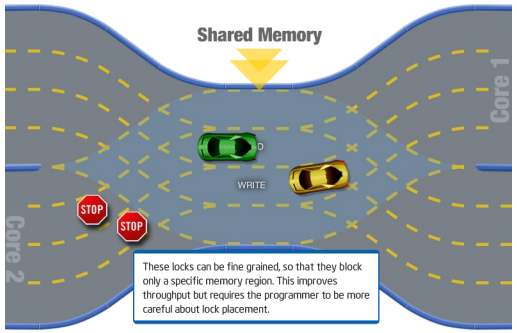


Example

```
void withdraw(account, amount) {
  lock(accounts[account].mutex);
  accounts[account] -= amount;
  release(accounts[account].mutex);
}
```

- Can scale well.
- Difficult to program.

Fine-Grained Locks Difficulties
Composition



Example

```
void transfer(fromAccount, toAccount, amount) {
  withdraw(fromAccount, amount);
  deposit(toAcount, amount);
}
```

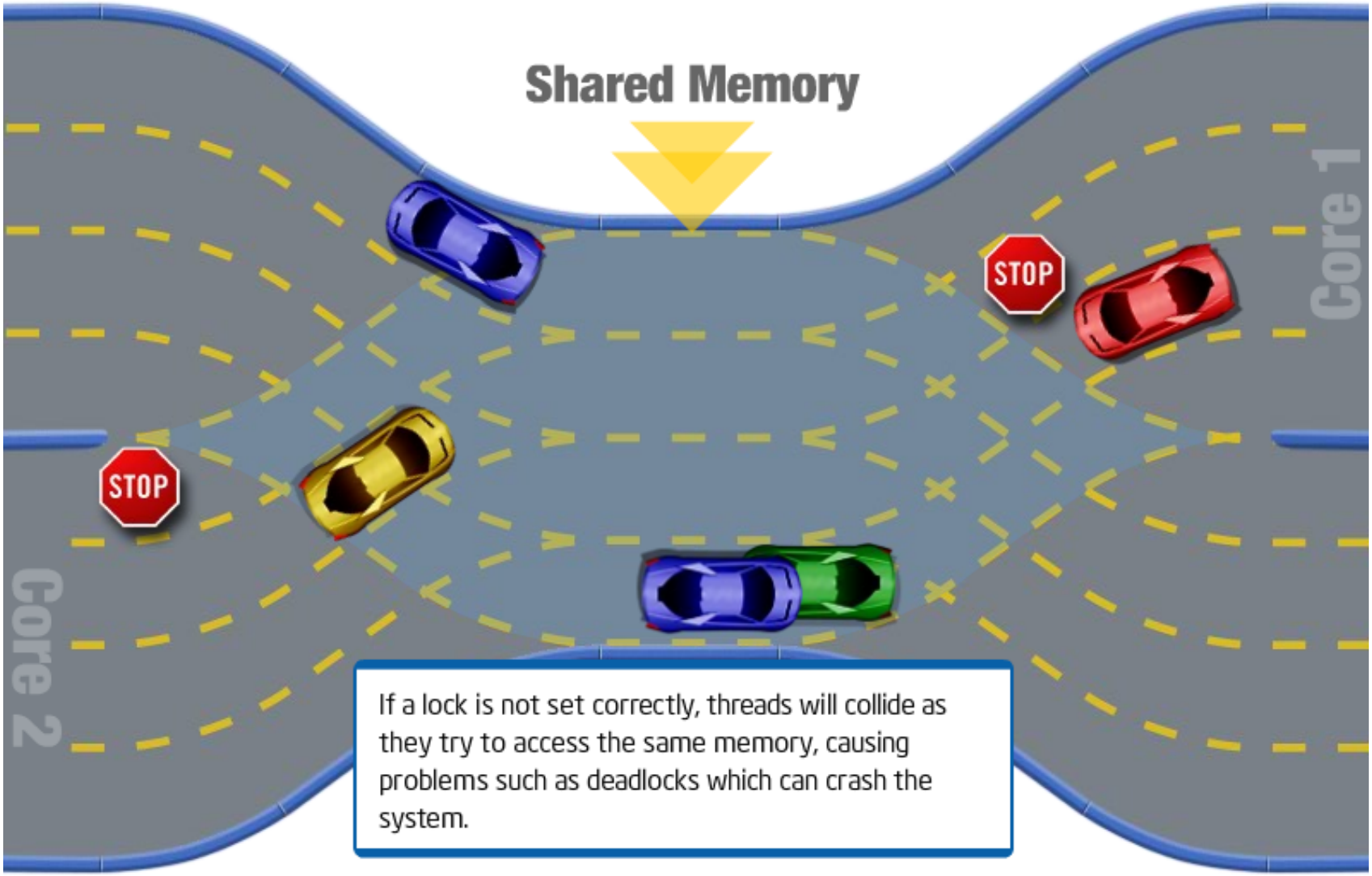
- Locking both accounts from `transfer` - breaks encapsulation, deadlocks.

Fine-Grained Locks Difficulties
Locking Policies

Comment from the linux kernel

```
/*
 * When a locked buffer is visible to the I/O layer
 * BH_Launder is set. This means before unlocking
 * we must clear BH_Launder,mb() on alpha and then
 * clear BH_Lock, so no reader can see BH_Launder set
 * on an unlocked buffer and then risk to deadlock.
 */
```

Fine-Grained Locks Difficulties



Transactional Memory

- Provide a simple API for programmers.
- Offering fast implementations.

Transactional Memory
Simple API

Example

```
void withdraw(account, amount) {
  atomic {
    accounts[account] -= amount;
  }
}
```

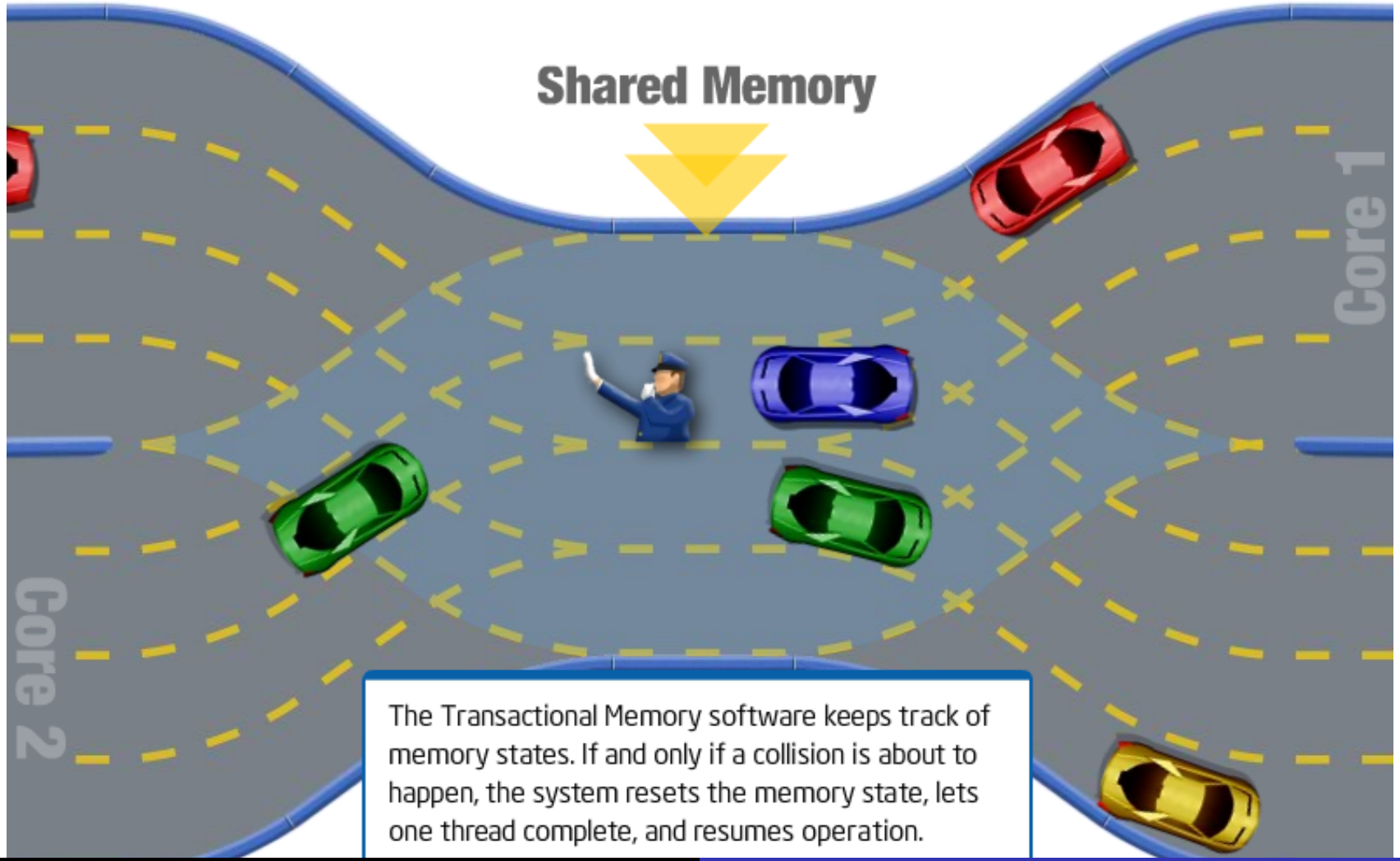
Nested transactions

```
void transfer(fromAccount, toAccount, amount) {
  atomic {
    withdraw(fromAccount, amount);
    deposit(toAcount, amount);
  }
}
```

Transactional Memory
Implementation

- A transaction is run speculatively without taking any locks.
- Collisions are detected either at commit time or during the run.
- On collision, one of the transactions is aborted and its changes are rolled back.
- Later the aborted transaction is restarted.

Transactional Memory
Implementation



Transactional Memory
Implementation by software

- All global memory accesses are handled by a special library.
- The library detects collisions and handles commits and aborts.

Transactional Memory
Implementation by hardware

- Reuse the cache coherency mechanism in multicore/multiprocessor machines.
- Requires special hardware.
- Limitations: Size and duration of transactions, context switches.

Existing Benchmarks

- Red-Black trees benchmarks
- STAMP benchmark suite.
  - Bayesian network learning
  - Gene sequencing
  - Network intrusion detection
  - K-means clustering
  - Maze routing
  - Graph kernels
  - Client/server travel reservation system
  - Delaunay mesh refinement

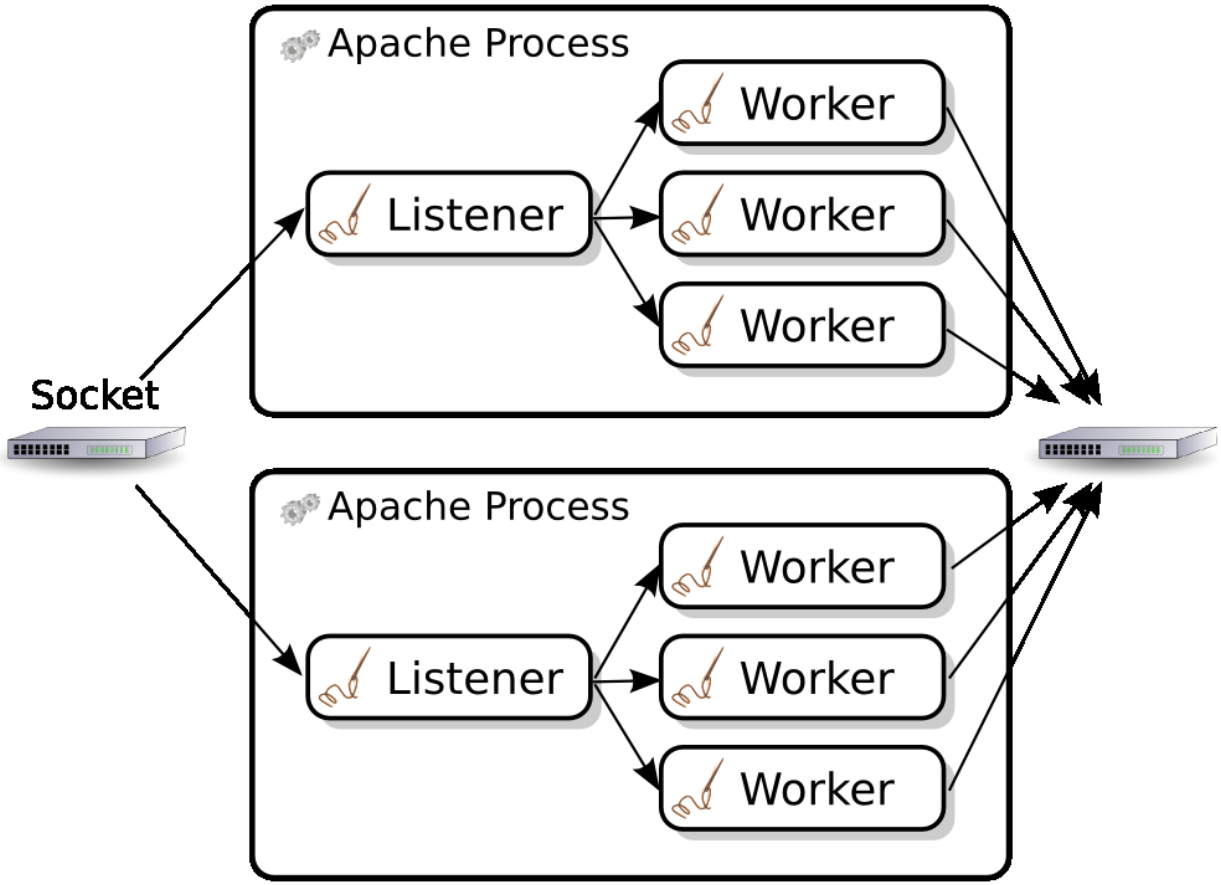
Our Project's Goal

Create a benchmark based on a real-world application for transactional memory.

Apache Web Server

- Written in C.
- Support many Multiprocessing Modules (MPMs): Parallel execution strategies.
- A mainly developed threaded MPM is the Worker MPM: Runs several processes, each running a fixed number of threads.

Apache Web Server
Worker MPM



Apache Cache Module - mod_mem_cache

- There isn't much interaction between the worker threads.
- The cache module enables worker threads of the same process to share cached pages in memory.
- Currently implemented with one big lock.

Software Transactional Memory in C/C++

Library based

- Transactions denoted by beginning and ending function calls.
- Require accessing global variables through library functions.

Compiler based

- Transactions are denoted by special syntax.
- Automatic conversion of memory access (transactification).

Compiler based STM

	Tanger	**ICC Experimental STM Compiler**
License	Open source	Licensed for personal use
Backend Compiler	LLVM	ICC
STM Library	Any / tinySTM	Intel ITM Library
Function Calls	Transactify All	`tm_callable`
Indirect Functions	Resolved, at run-time	
Library Functions	Limited, Tarifa	`malloc`, `free`, some `stdlib.h`

Commit handlers

A common pattern we found, missing in both Tanger and ICC.

Example

```
__tm_atomic {
  if (--obj->refcount == 0) {
    cache_remove(cache, obj);
    cleanup_cache_object(obj);
  }
}
```

Commit handlers

Should be converted to:

Example

```
__tm_atomic {
  if (--obj->refcount == 0) {
    cache_remove(cache, obj);
  }
}
if (obj->refcount == 0)
  cleanup_cache_object(obj);
```

Commit handlers

It would be nice to have:

Example

```
__tm_atomic {
  if (--obj->refcount == 0) {
    cache_remove(cache, obj);
    on_commit(&cleanup_cache_object, obj);
  }
}
```

Evaluation

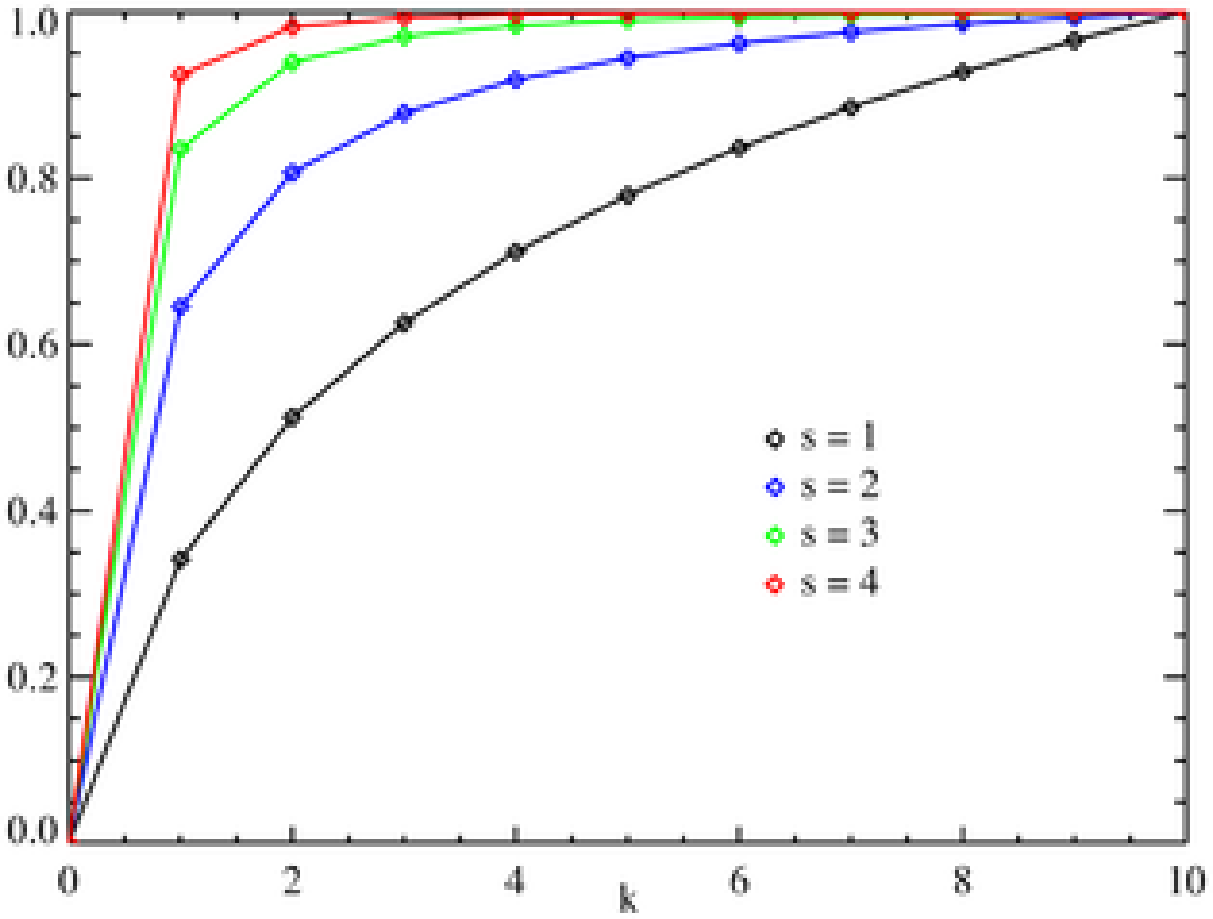
Evaluation of a web server requires:

- A data set.
- Client strategy

We chose

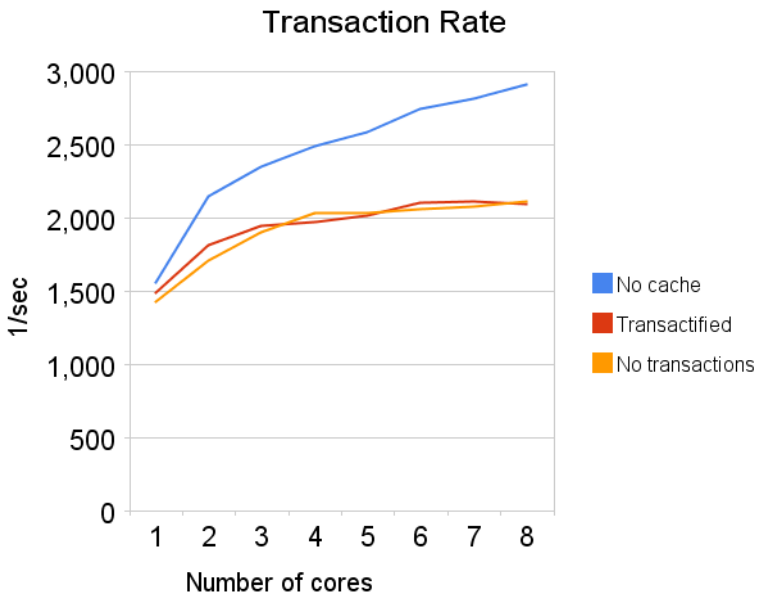
- Data set of small files (man pages) so that the throughput of the NIC won't be the bottleneck.
- Running as many clients concurrently as possible to create contention on the server and its cache.
- Requesting pages according to Zipf distribution - to control locality.

Zipf Distribution

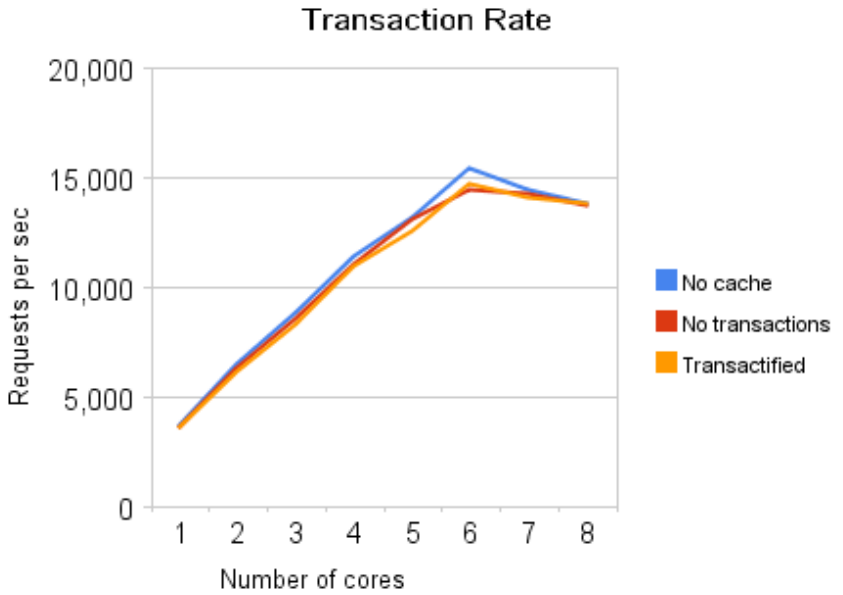


Initial Results

$s = 0.5$



$s = 1$



Computational Workload

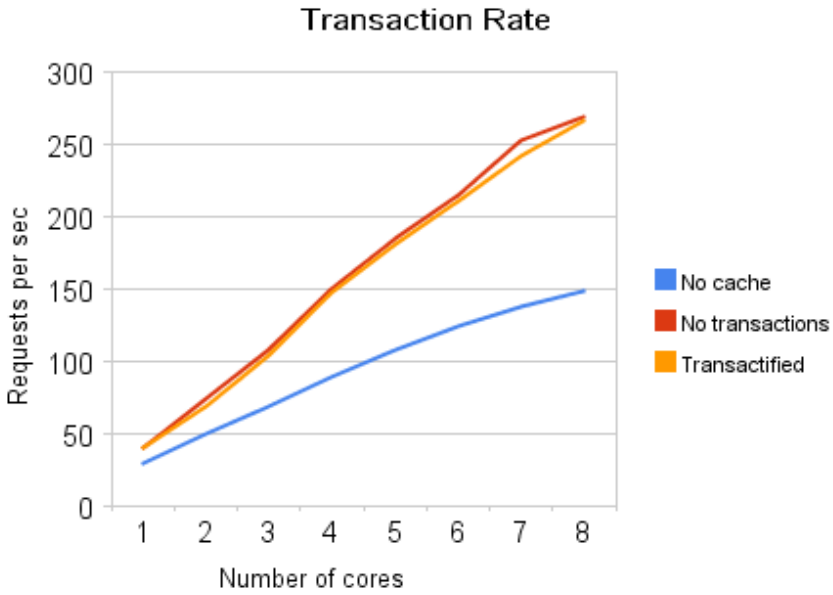
Theory

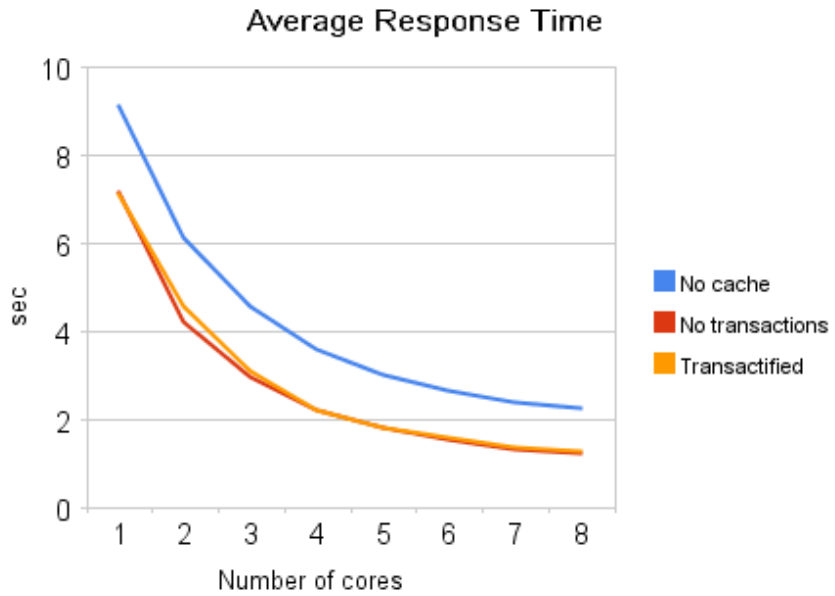
- The linux file cache contains the entire data set $\Rightarrow$ Apache's cache just gets in the way.
- Dynamically generated content might give the cache an advantage.

- Serve the same workload though `man2html`, uncompressing and converting the files to HTML.

Computational Workload

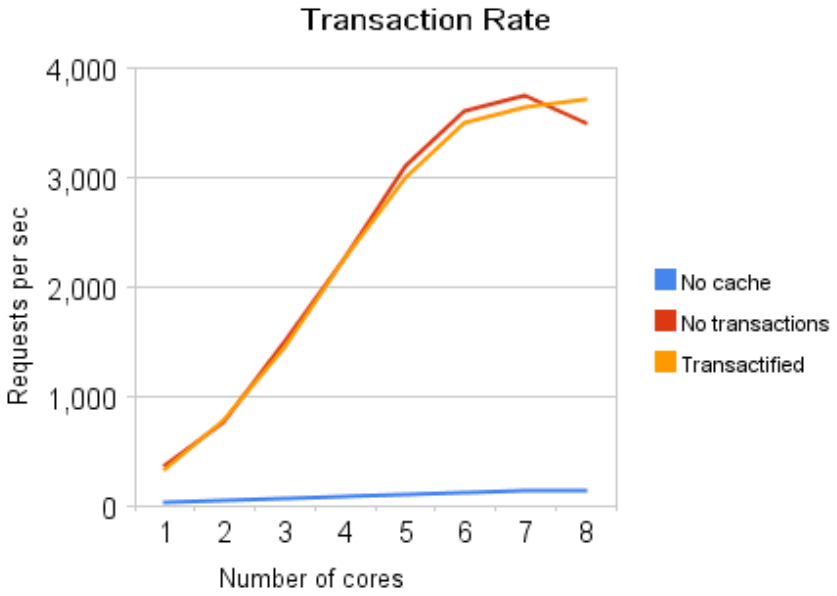
$s = 1$

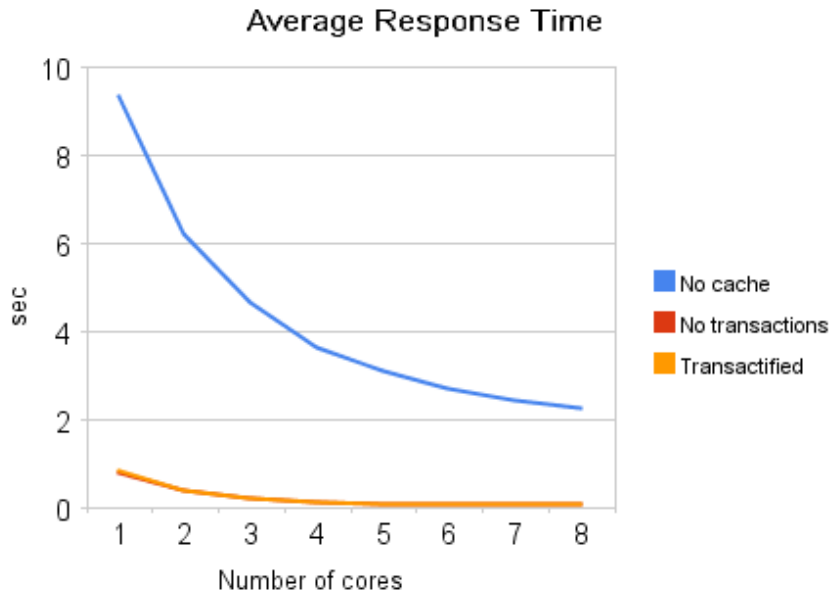




Computational Workload

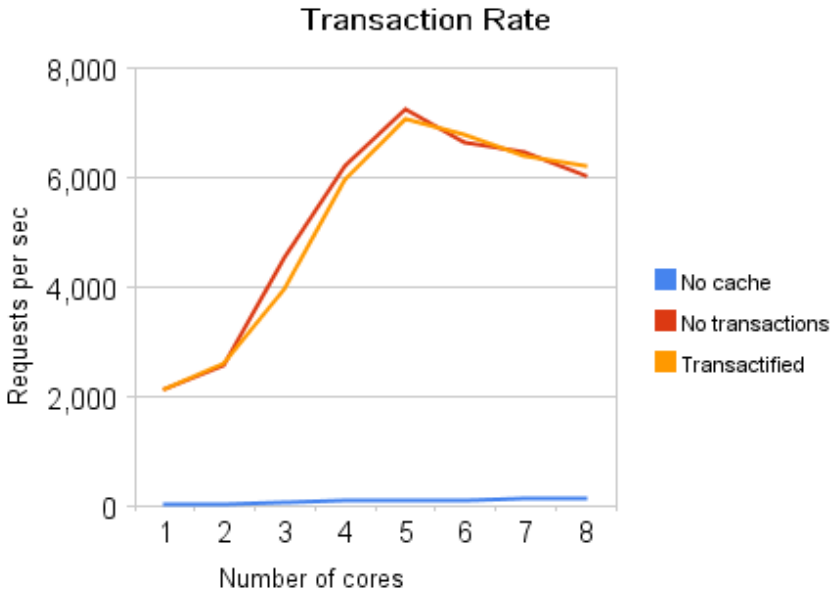
$s = 2$

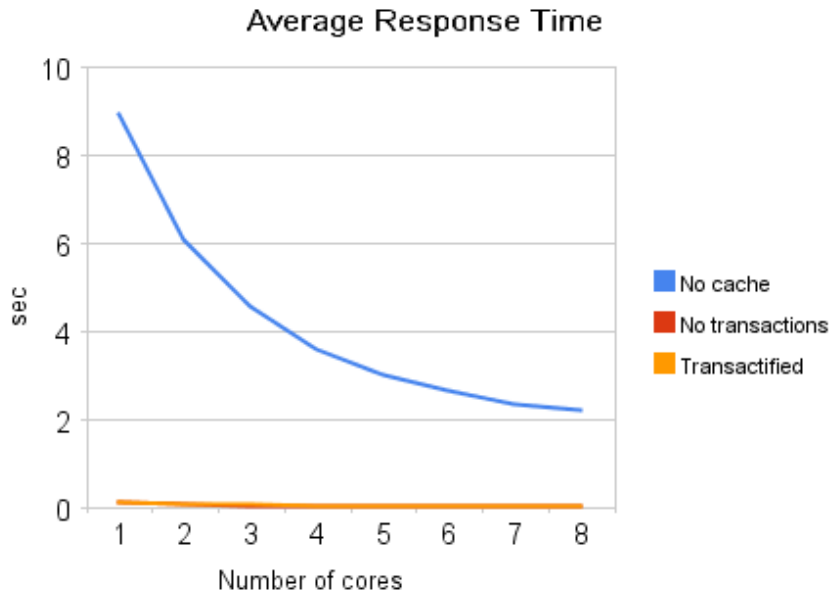




Computational Workload

$s = 3$





Thank you

Credits

- The car analogy graphics from Intel's presentation.
- The kernel quote from Maurice Herlihy's presentation.

Questions

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