

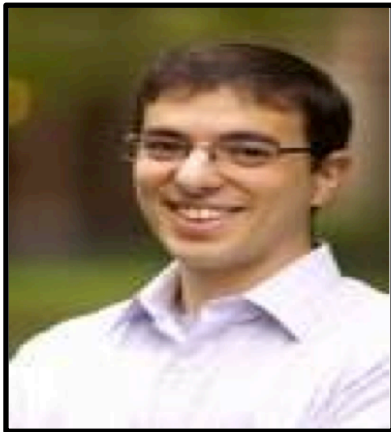
# Lazy Evaluation of Transactions in Database Systems

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Daniel J. Abadi◆

◆Yale University, ★Google

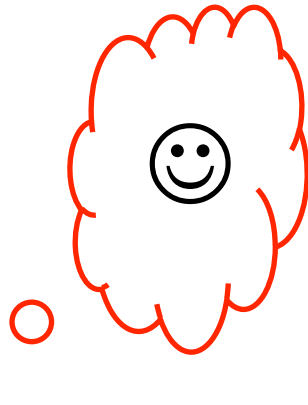


Paper “X” looks relevant,  
can you add it to related  
work?



Just read through the whole  
thing and added to related work.  
Our work is more ACIDic





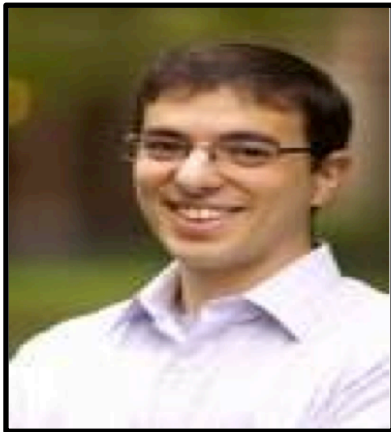
In reality...

- Read only abstract to give a sensible response
- Keep “sticky” note on desk to later read paper and write related work.



Read paper X

Add to  
related work



Read paper X

Add to  
related work

Read paper Y

Add to  
related work

...

Read paper Z

Add to  
related work

Hey, can you check-in your additions to related work? I can't see your changes...



Read paper X

Add to  
related work

Read paper Y

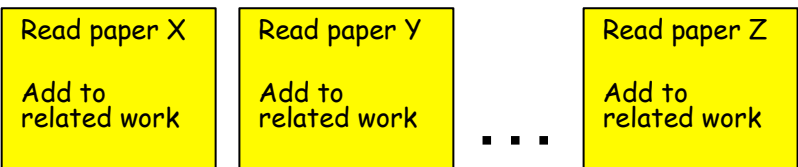
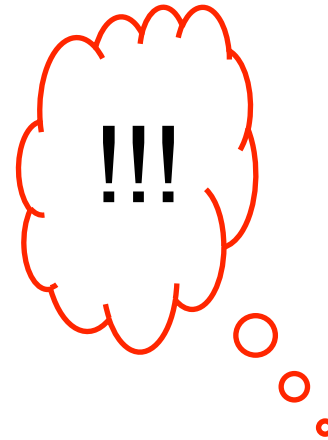
Add to  
related work

...

Read paper Z

Add to  
related work





- Previously said I did all the work. Can't feign ignorance.
- Use information on stickies to read papers and finish writing related work.



Read paper X

Add to  
related work

Read paper Y

Add to  
related work

...

Read paper Z

Add to  
related work

# Lazy Database Systems

- Promise to commit/abort while only partially executing txns
- Keep promises while maintaining ACID and serializability

# Lying Considered ~~Harmful~~ Useful

- Flexibility to execute transactions when most favorable
  - Cache Locality
  - Load Balancing
  - Contention Reduction

# Can't Keep Lying Forever



Must satisfy “external”  
reads

# Talk Outline

- **Lazy Database Design**
- Benefits of Lazy Execution
- Experimental Evaluation
- Conclusion

# Customer Orders Product

Update product  
inventory

Compute  
discounted price

Update customer  
bill

# Customer Orders Product

Update product  
inventory

Compute  
discounted price

Update customer  
bill

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**



# Customer Orders Product

Update product  
inventory

**Compute  
discounted price**

Update customer  
bill

```
Read Product record
```

```
Product count -= 1
```

```
If Product count < 0:
```

```
    ABORT()
```

```
Read daily discount
```

```
Compute discounted price
```

# Customer Orders Product

Update product  
inventory

Compute  
discounted price

Update customer  
bill

```
Read Product record  
  
Product count -= 1  
  
If Product count < 0:  
    ABORT()  
  
Read daily discount  
  
Compute discounted price
```

Read customer's monthly  
bill record

Customer's monthly bill +=  
Discounted price

COMMIT()

# We Ask the Question

Can we:  
return commit/abort  
promise ...

without executing to  
completion...

while maintaining  
ACID and  
serializability?

```
Read Product record
```

```
Product count -= 1
```

```
If Product count < 0:
```

```
    ABORT()
```

```
Read daily discount
```

```
Compute discounted price
```

```
Read customer's monthly  
bill record
```

```
Customer's monthly bill +=  
    Discounted price
```

```
COMMIT()
```

# Our Solution

- Split up transactions into two parts
  - Give users the illusion that execution is atomic
- First part produces commit/abort promise
  - Executes immediately
- Second part does everything else
  - Execution is deferred

# How to Split a Transaction?

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Discounted price

**COMMIT()**

# Splitting a Transaction

Abort due to  
txn logic

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Discounted price

**COMMIT()**

# Splitting a Transaction

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Discounted price

**COMMIT()**

Return  
commit  
promise



# Splitting a Transaction

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Discounted price

**COMMIT()**



# Splitting a Transaction

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

**COMMIT\_PROMISE()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Product price

# Splitting a Transaction

Execute immediately



```
graph TD; A[Execute immediately] --> B[Read Product record<br/>Product count -= 1<br/>If Product count < 0:<br/>  ABORT()<br/>  COMMIT_PROMISE()]; C[Defer execution] --> D[Read daily discount<br/>Compute discounted price<br/>Read customer's monthly bill record<br/>Customer's monthly bill += Product price];
```

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

**COMMIT\_PROMISE()**

Read daily discount

Compute discounted price

Read customer's monthly  
bill record

Customer's monthly bill +=  
Product price


Defer execution

# Dealing with Deferred Logic

- Don't write out actual record values
- ***Blindly*** insert placeholders corresponding to unexecuted deferred logic
  - Similar to stickies on my desk as reminders

# Dealing with Deferred Logic

## Monthly Bill

John	\$17.05
Mary	
⋮	
David	\$300

Read Tuesday's discount

Compute discounted price

Read customer's monthly bill record


Mary's monthly bill +=  
Product price

# Processing External Reads

- External read may depend on a deferred transaction
- Deferred transaction itself may have dependencies

# Dealing with Deferred Logic

## Monthly Bill

John	\$17.05
Mary	
⋮	
David	\$300


Read Tuesday's discount

Compute discounted price

Read customer's monthly bill record

Mary's monthly bill += Product price

## Daily Discount

Monday	5%
Tuesday	
⋮	
Friday	15%

Increase Tuesday's discount by 10%

# Dealing with Deferred Logic

## Monthly Bill

John	\$17.05
Mary	<input type="text"/>
⋮	
David	\$300

Read Tuesday's discount

Compute discounted price

Read customer's monthly bill record

Mary's monthly bill += Product price

## Daily Discount

Monday	5%
Tuesday	<input type="text"/>
⋮	
Friday	15%

Increase Tuesday's discount by 10%

# Dealing with Deferred Logic

Deferred pieces of logic  
are implicitly ordered

```
Read Tuesday's discount  
Compute discounted price  
Read customer's monthly  
bill record  
Mary's monthly bill +=  
    Product price
```

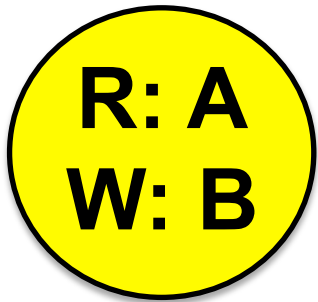


```
Increase Tuesday's  
discount by 10%
```

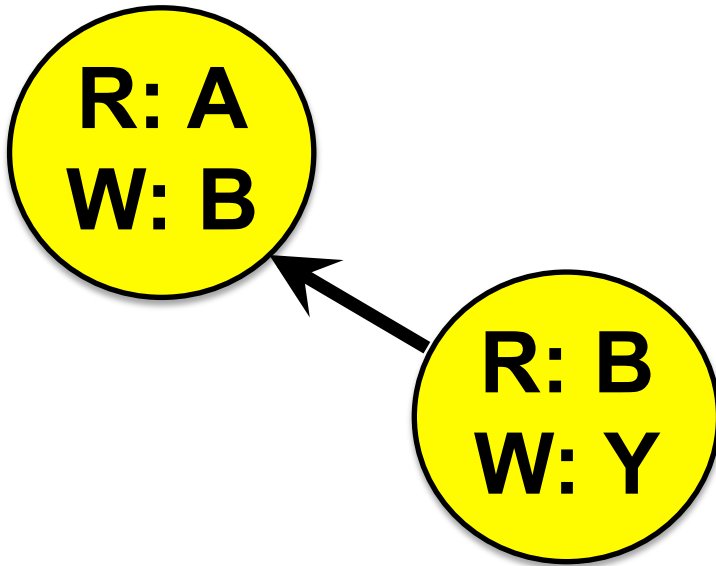


# Dependency Graph of Transactions

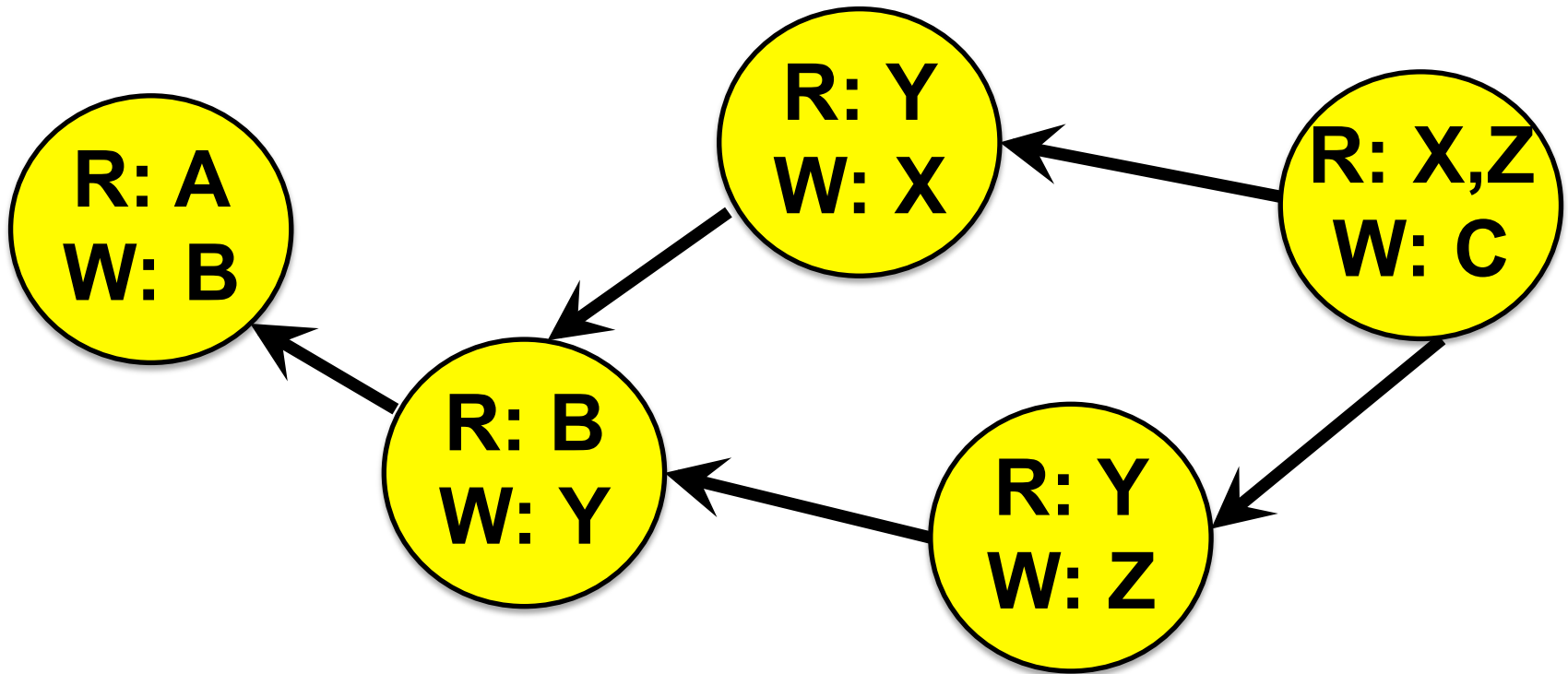
# Dependency Graph of Transactions



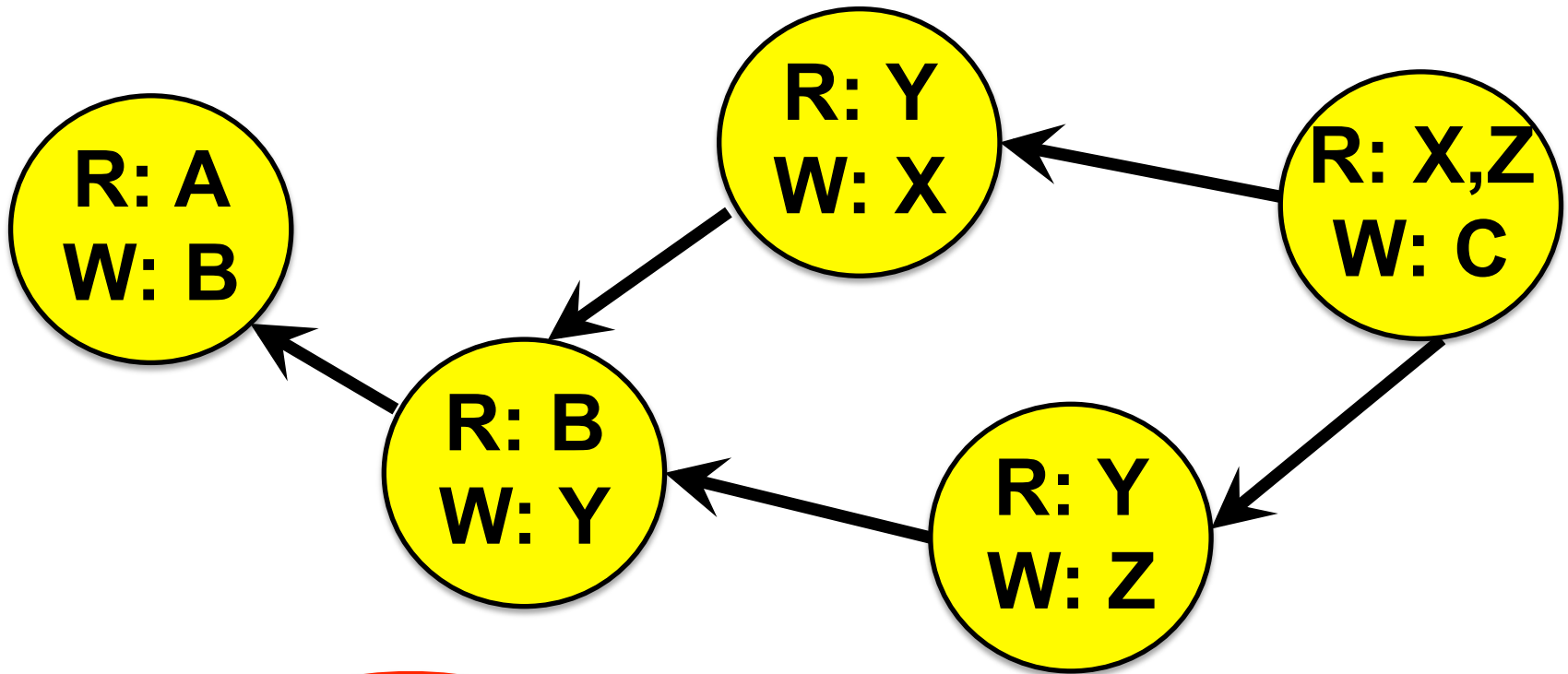
# Dependency Graph of Transactions



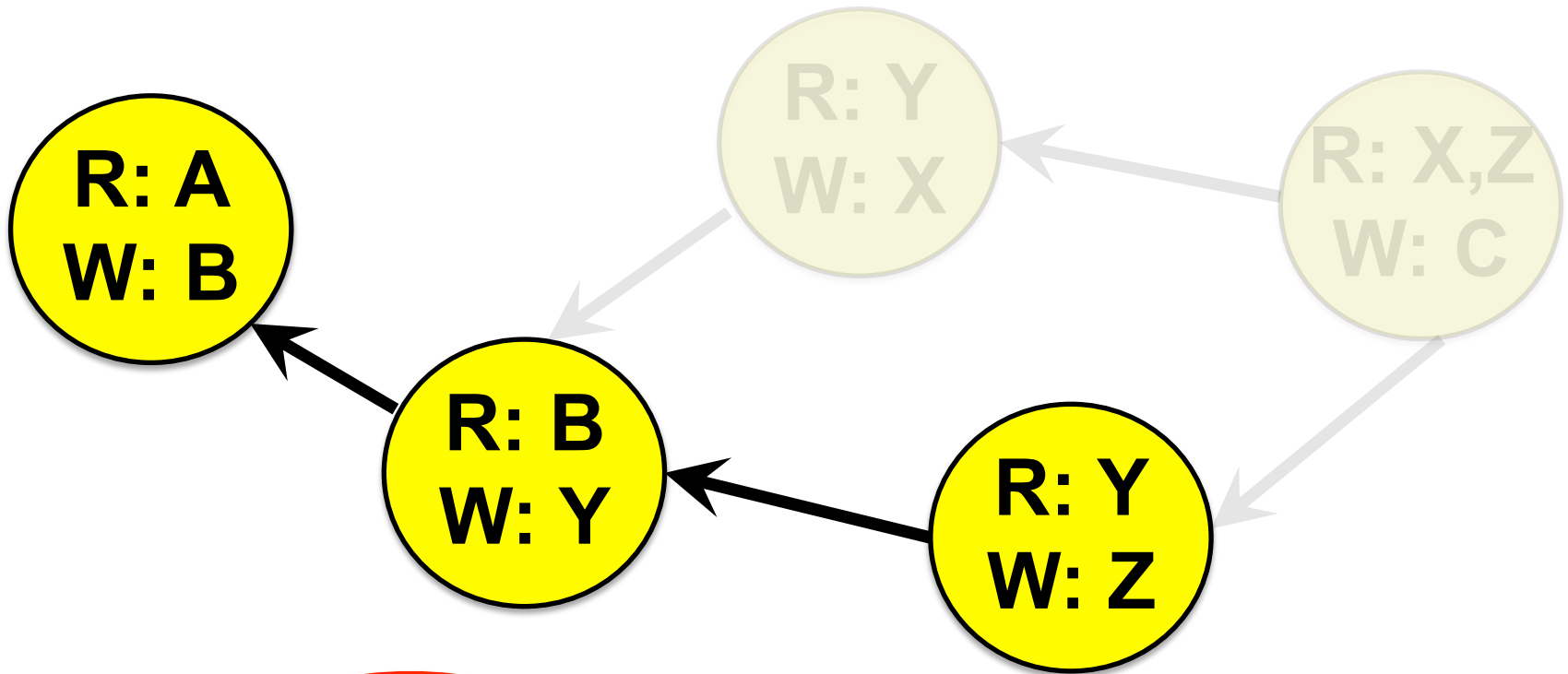
# Dependency Graph of Transactions



# Dependency Graph of Transactions



# Dependency Graph of Transactions



Execute last writer  
and its transitive  
closure

# Large Transitive Closures

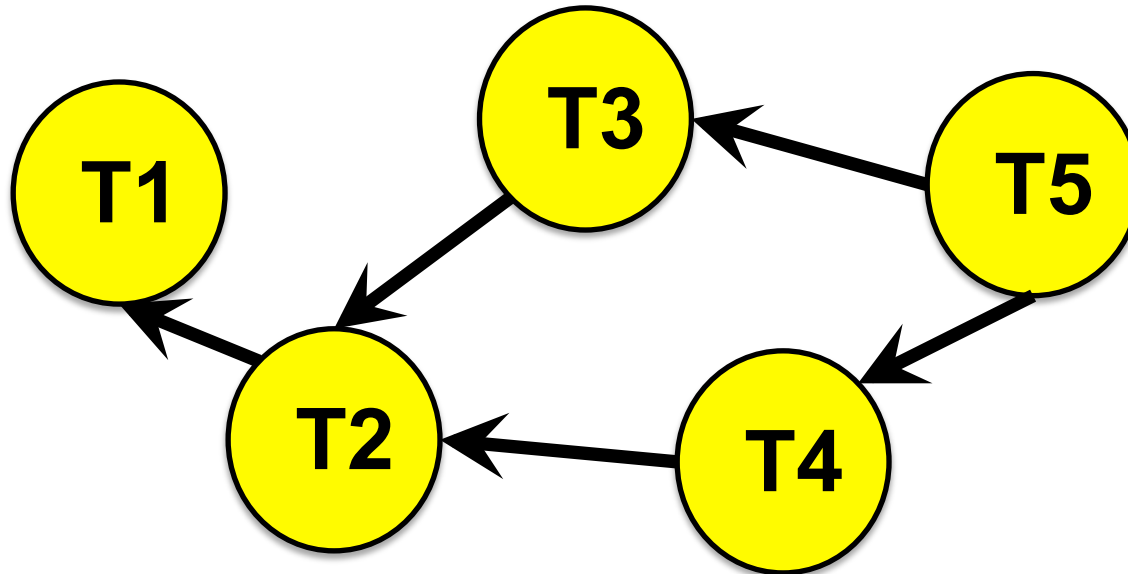
- The subset of the graph a record depends on may grow very large
  - High external read latency

# Large Transitive Closures

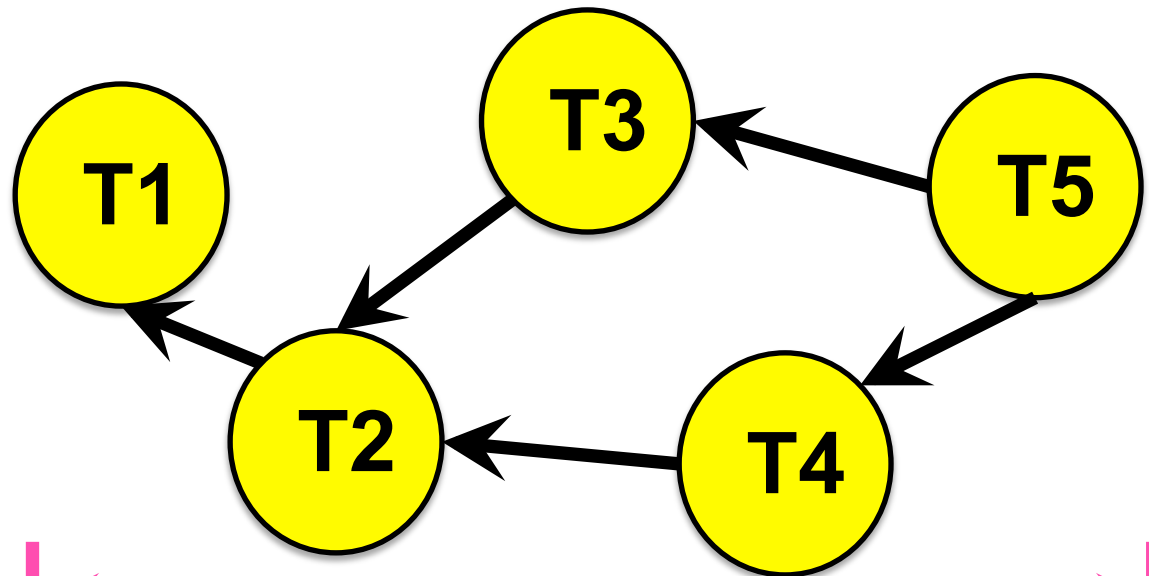
- The subset of the graph a record depends on may grow very large
  - High external read latency
  - **Incrementally process transactions in the background**



# Incremental Transaction Processing

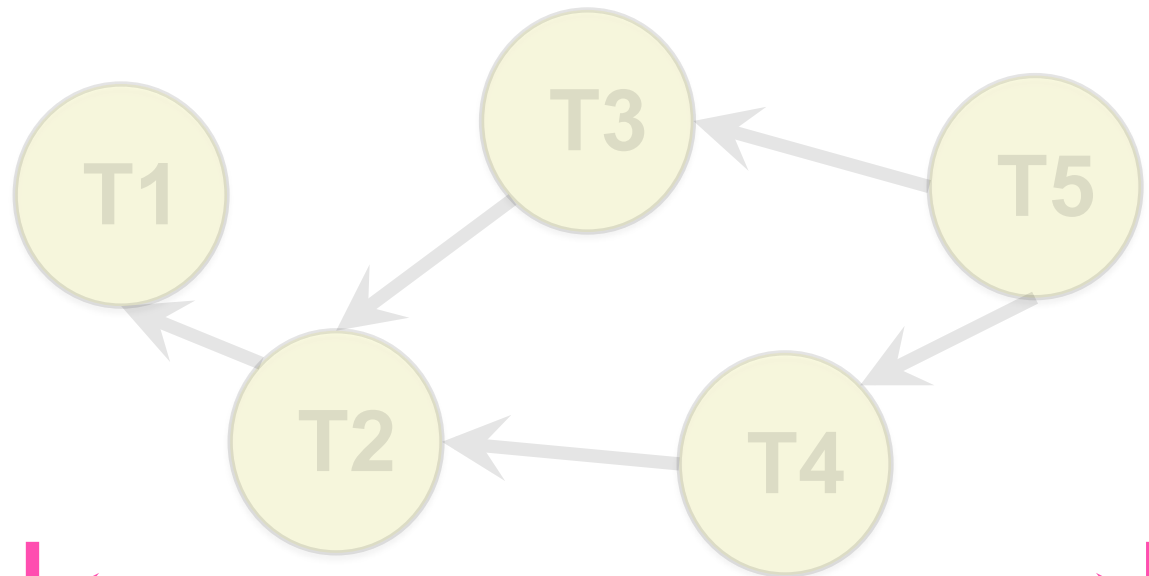


# Incremental Transaction Processing



Bound the maximum  
depth of the dependency  
graph

# Incremental Transaction Processing



Bound the maximum  
depth of the dependency  
graph

# Incremental Transaction Processing

Tradeoff:

- Higher bound means larger batches (good for cache locality)
- Larger batches mean increased external read latency

# Talk Outline

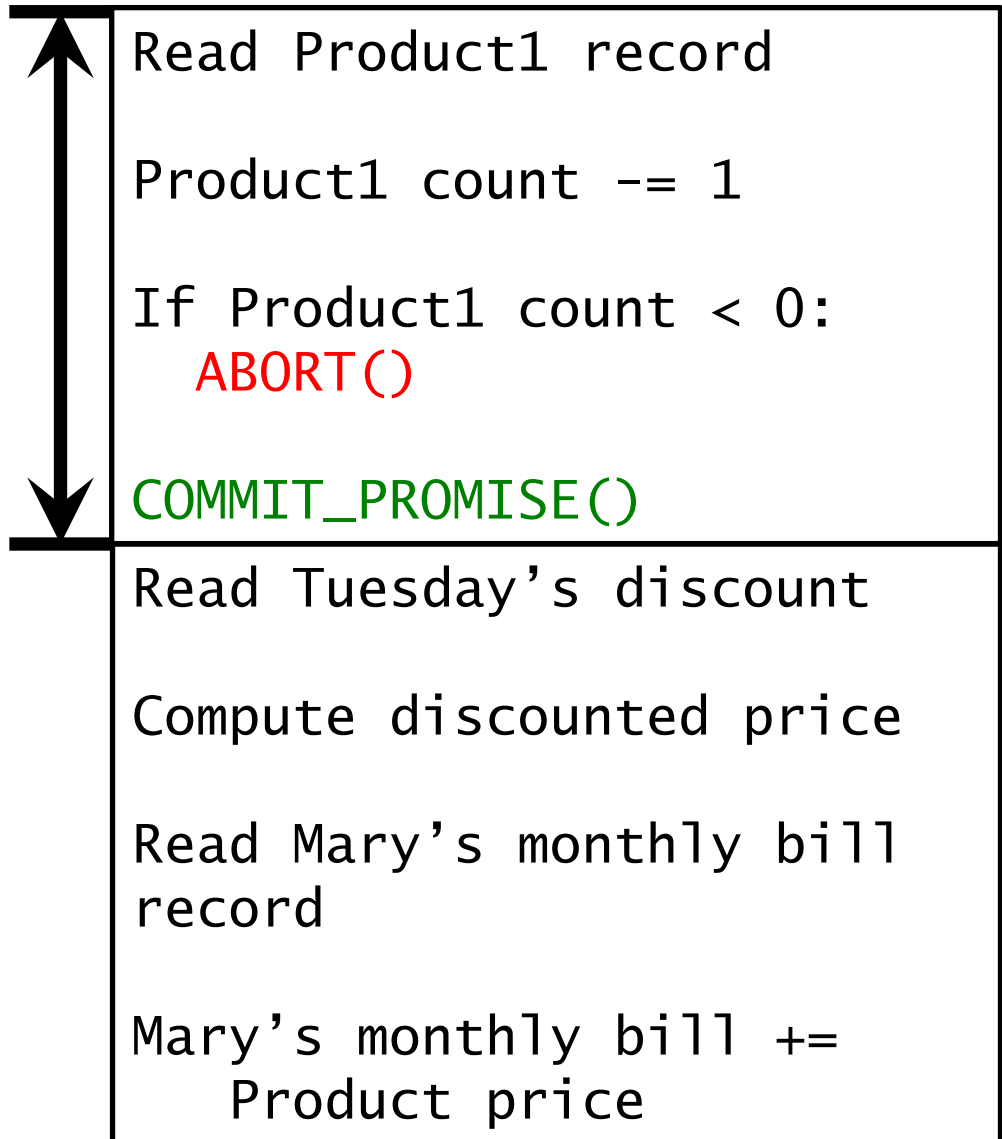
- Lazy Database Design
- **Benefits of Lazy Execution**
- Experimental Evaluation
- Conclusion

# Benefits of Lazy Transactions

- Data Cache/Buffer Pool Locality
- Temporal Load Balancing
- Reduced Contention

# Data Cache/Buffer Pool Locality

Execute  
immediately



# Data Cache/Buffer Pool Locality

```
Read Tuesday's discount  
Compute discounted price  
Read Mary's monthly bill  
record  
Mary's monthly bill +=  
    Product price
```

Deferred



# Data Cache/Buffer Pool Locality

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product1 price

Insert a record into  
Orders table

Deferred

Read Product2 record

Product2 count -= 1

If Product2 count < 0:

**ABORT()**

**COMMIT\_PROMISE()**

Read Monday's discount

Compute discounted price

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product price

# Data Cache/Buffer Pool Locality

Read Mary's monthly bill

re Read Monday's discount

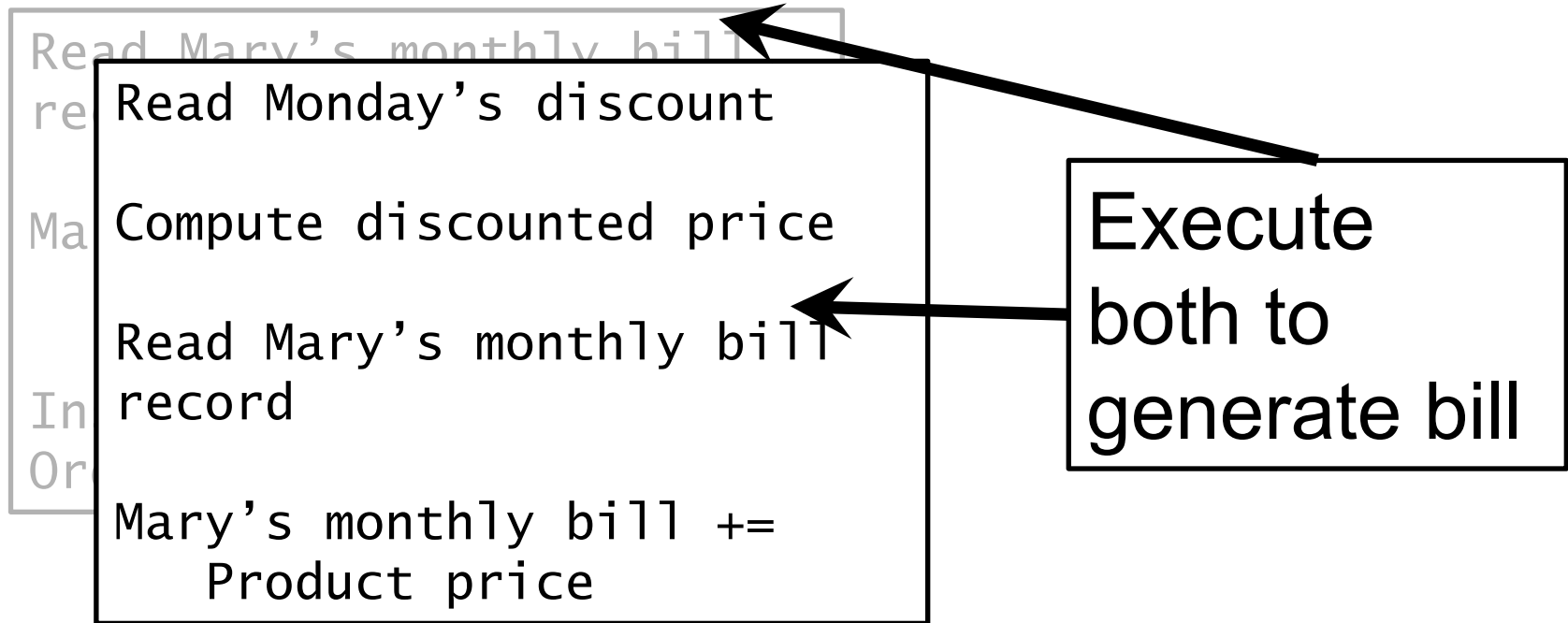
Ma Compute discounted price

In Read Mary's monthly bill  
Or record

Mary's monthly bill +=  
Product price

Deferred

# Data Cache/Buffer Pool Locality



Deferred

# Data Cache/Buffer Pool Locality

Read Monday's discount

Compute discounted price

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product2 price

Read Tuesday's discount

Compute discounted price

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product1 price

Deferred

Both update  
the same bill

```
graph TD; A[Both update the same bill] --> B[Read Monday's discount<br/>Compute discounted price<br/>Read Mary's monthly bill record<br/>Mary's monthly bill += Product2 price]; A --> C[Read Tuesday's discount<br/>Compute discounted price<br/>Read Mary's monthly bill record<br/>Mary's monthly bill += Product1 price];
```

# Data Cache/Buffer Pool Locality

Read Monday's discount

Compute discounted price

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product2 price

Read Tuesday's discount

Compute discounted price

Read Mary's monthly bill  
record

Mary's monthly bill +=  
Product1 price

Deferred

Bring Mary's bill  
record into cache  
just once

```
graph TD; subgraph Deferred; direction TB; B1[Read Monday's discount<br/>Compute discounted price<br/>Read Mary's monthly bill record<br/>Mary's monthly bill += Product2 price]; B2[Read Tuesday's discount<br/>Compute discounted price<br/>Read Mary's monthly bill record<br/>Mary's monthly bill += Product1 price]; end; C[Bring Mary's bill record into cache just once]; C --> B1; C --> B2;
```

# Temporal Load Balancing

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read Customer's monthly  
bill record

Customer's monthly bill +=  
Product price

**COMMIT()**

Read Product record

Product count -= 1

If Product count < 0:

**ABORT()**

**COMMIT\_PROMISE()**

Read daily discount

Compute discounted price

Read Customer's monthly  
bill record

Customer's monthly bill +=  
Product price

# Temporal Load Balancing

Read Product record

Product count -= 1

If Product count < 0:  
**ABORT()**

Read daily discount

Compute discounted price

Read Customer's monthly  
bill record

Customer's monthly bill +=  
Product price

**COMMIT()**

Read Product record

Product count -= 1

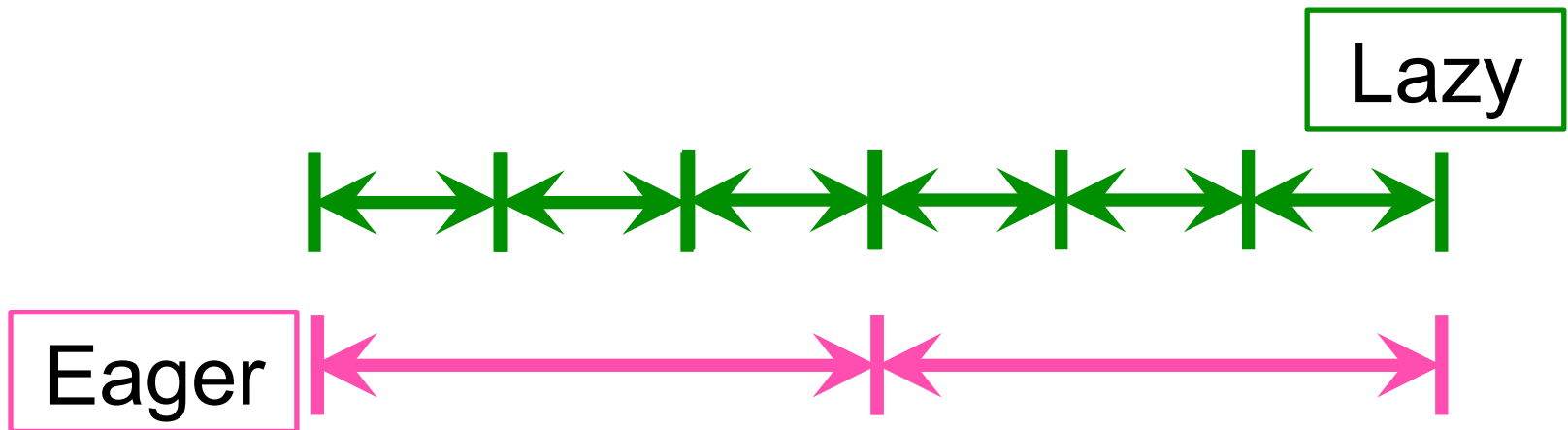
If Product count < 0:  
**ABORT()**

**COMMIT\_PROMISE()**

Arrows represent  
time required to  
immediately process  
transactions

# Temporal Load Balancing

More commit  
decisions per  
unit time





# Reduced Contention

Popular item

Read **iThing** record

**iThing** count -= 1

If **iThing** count < 0:

**ABORT()**

Read daily discount

Compute discounted price

Read Fanboy1's monthly  
bill record

Fanboy1's monthly bill +=  
Discounted price

**COMMIT()**

# Reduced Contention

Lock must  
be held for  
this period



```
Read iThing record
```

```
iThing count -= 1
```

```
If iThing count < 0:
```

```
    ABORT()
```

```
Read daily discount
```

```
Compute discounted price
```

```
Read Fanboy1's monthly  
bill record
```

```
Fanboy1's monthly bill +=  
    Discounted price
```

```
COMMIT()
```

# Reduced Contention

Hold  
contended  
lock for less  
time

Read **iThing** record

**iThing** count -= 1

If **iThing** count < 0:  
**ABORT()**

**COMMIT\_PROMISE()**

Read daily discount

Compute discounted price

Read Fanboy1's monthly  
bill record

Fanboy1's monthly bill +=  
Discounted price

# Talk Outline

- Lazy Database Design
- Benefits of Lazy Execution
- **Experimental Evaluation**
- Conclusion

# Experimental Setup

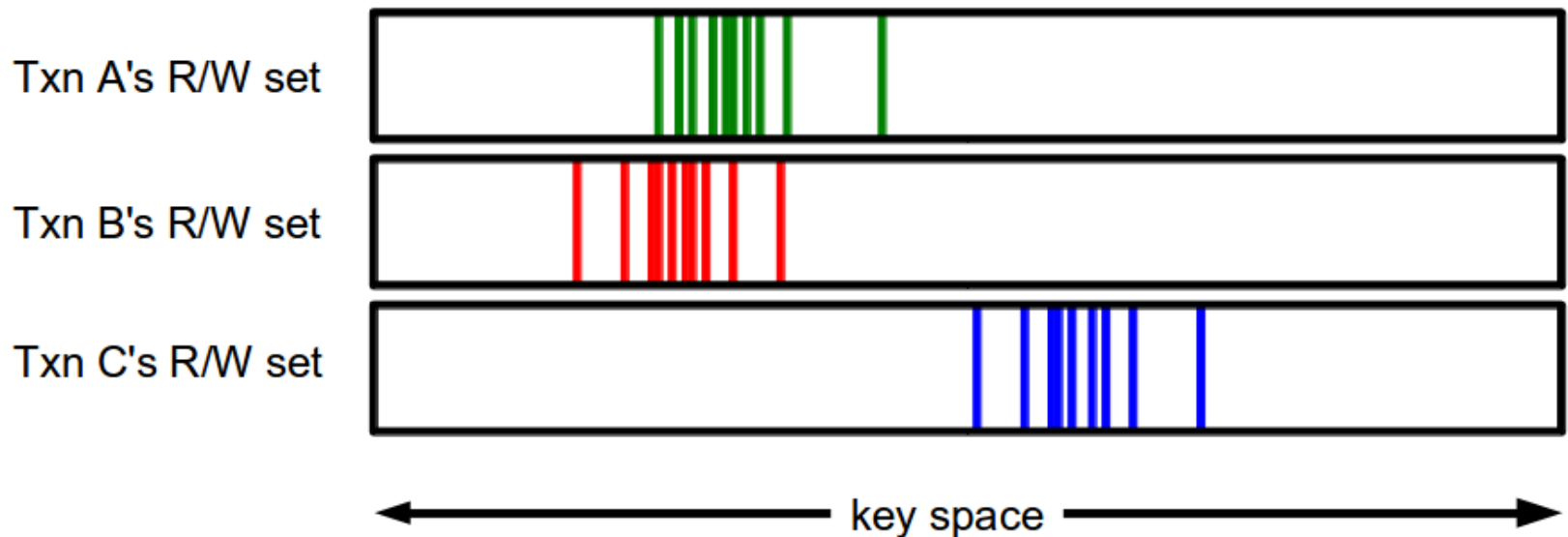
- All data in memory
- Single machine
- 8 cores
  - Lazy: 1 commit/abort + 7 deferred logic
  - Eager: 8 cores

# Experimental Evaluation

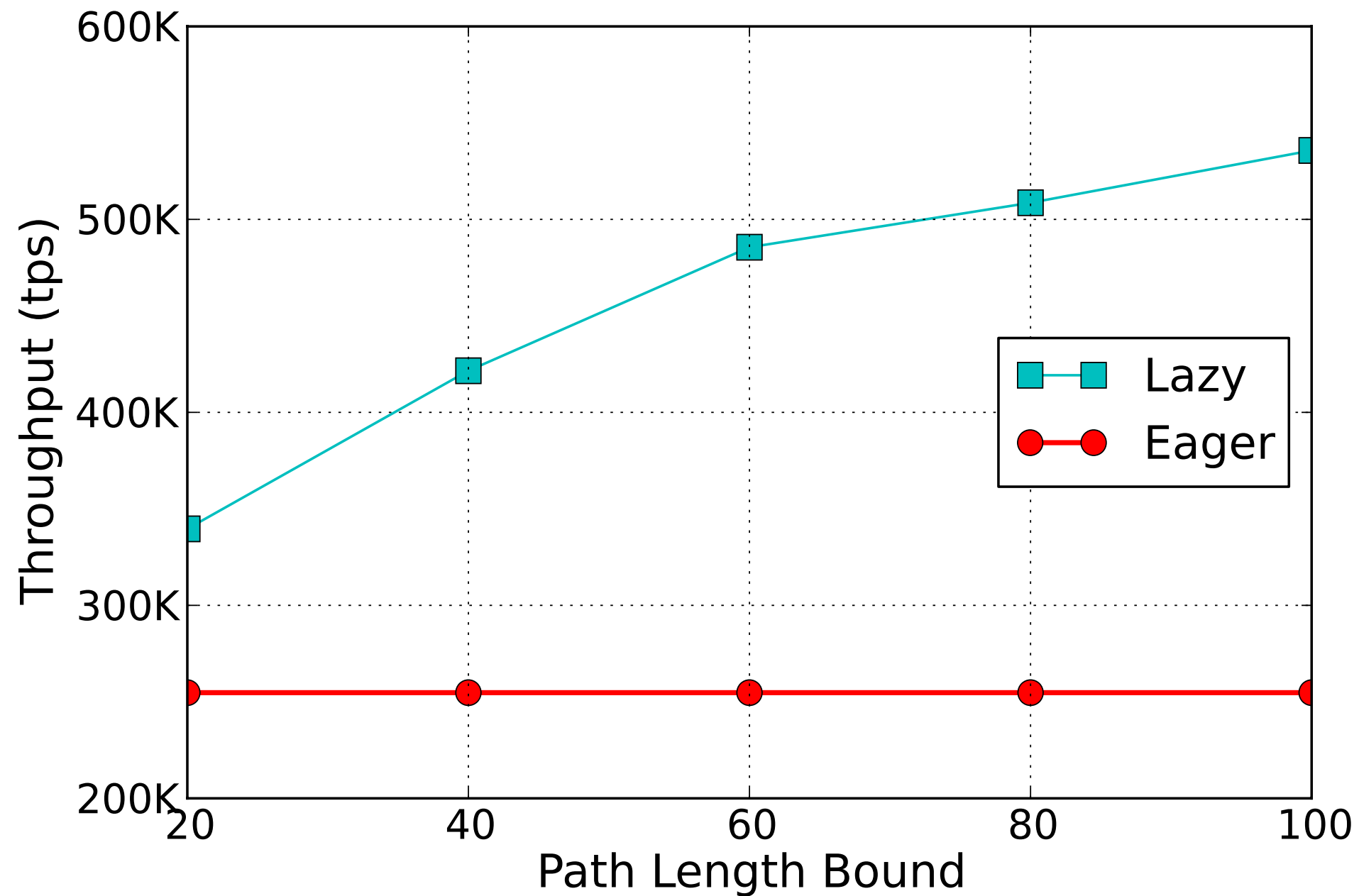
- Cache Locality
- External Read Latency
- Temporal Load Balancing
- Contention Reduction

# Cache-Locality

- “Cliquesy” workload
- Conflicting transactions conflict on several records

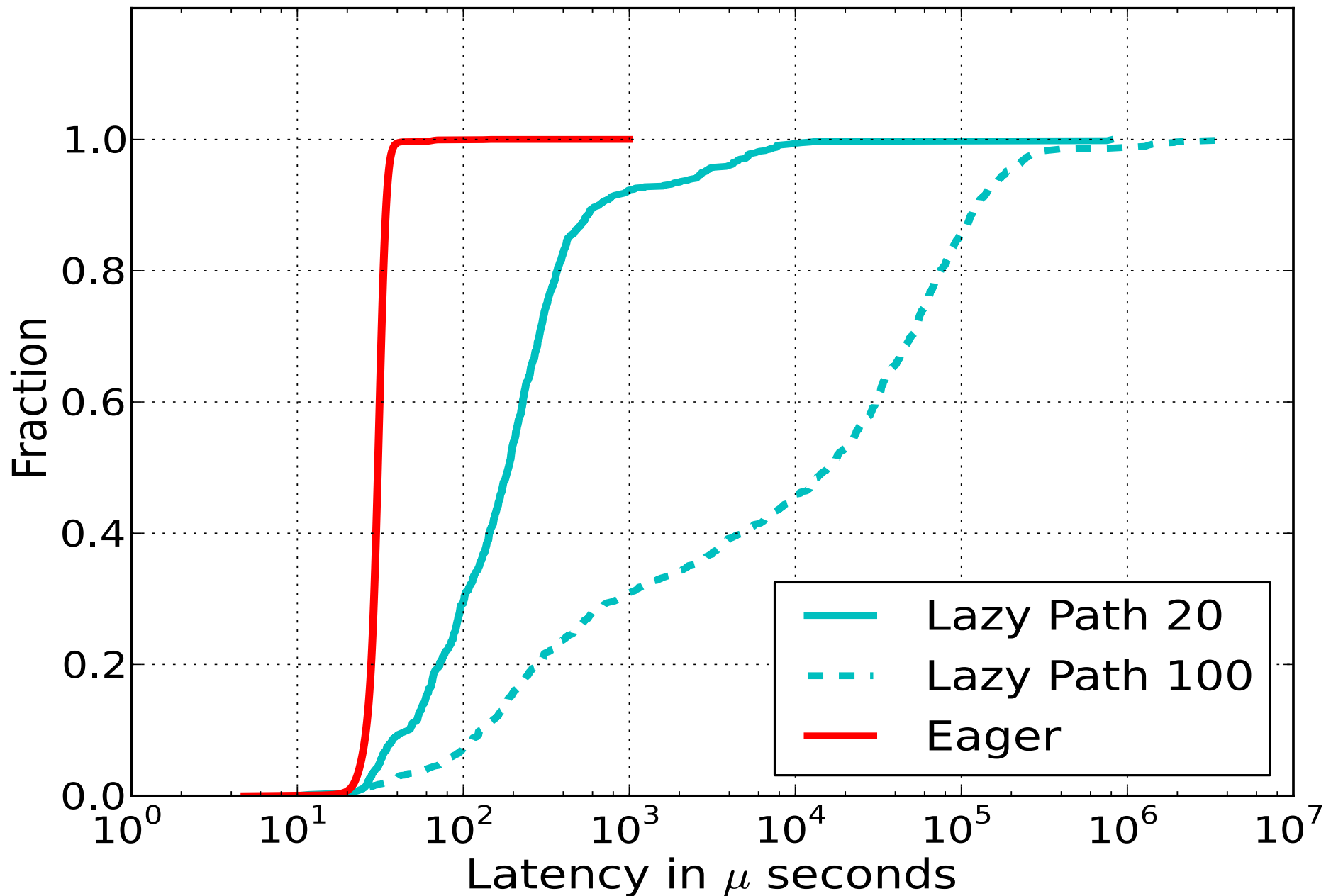


# Cache-Locality





# External Read Latency CDF

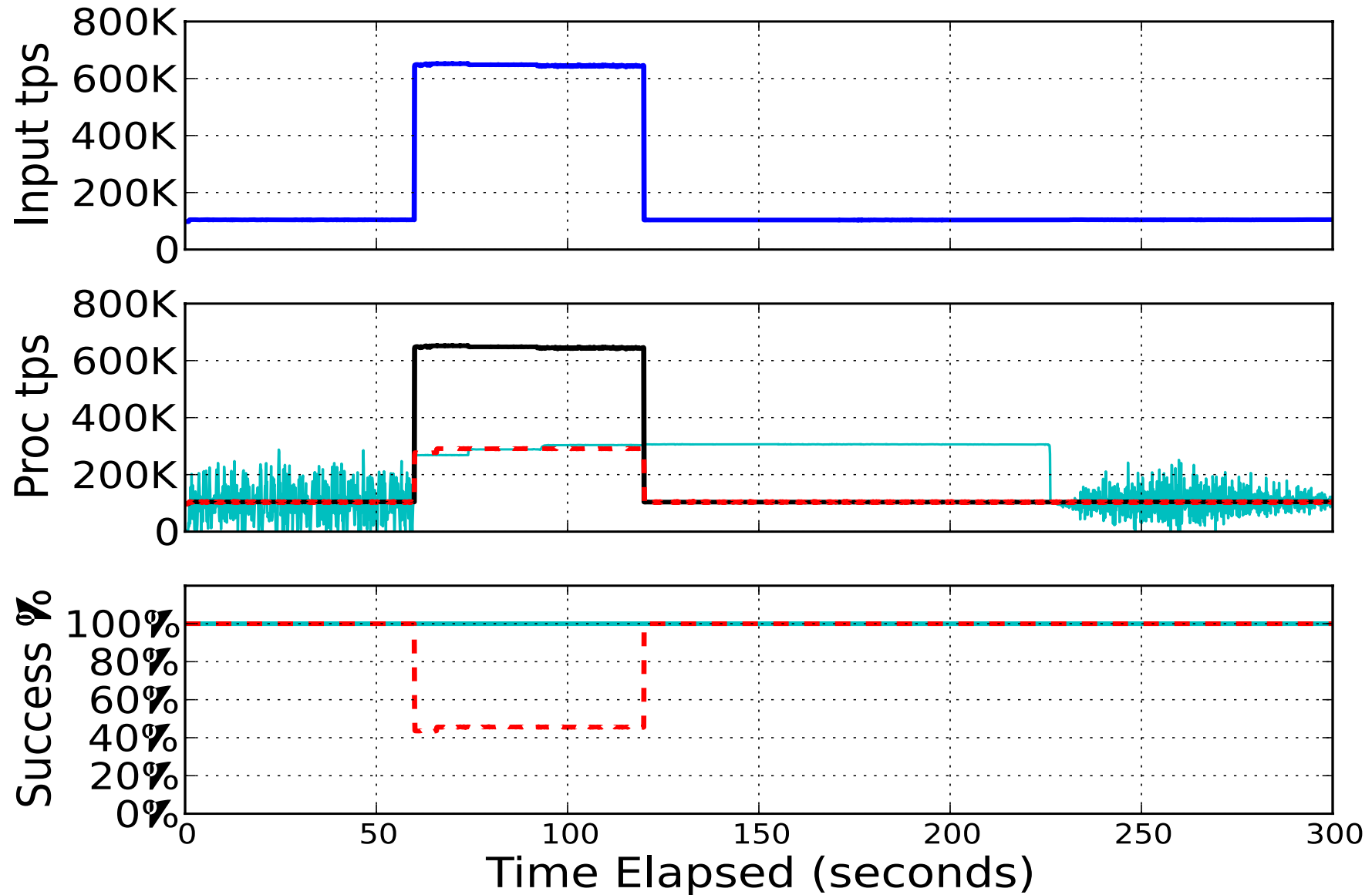


# Temporal Load Balancing

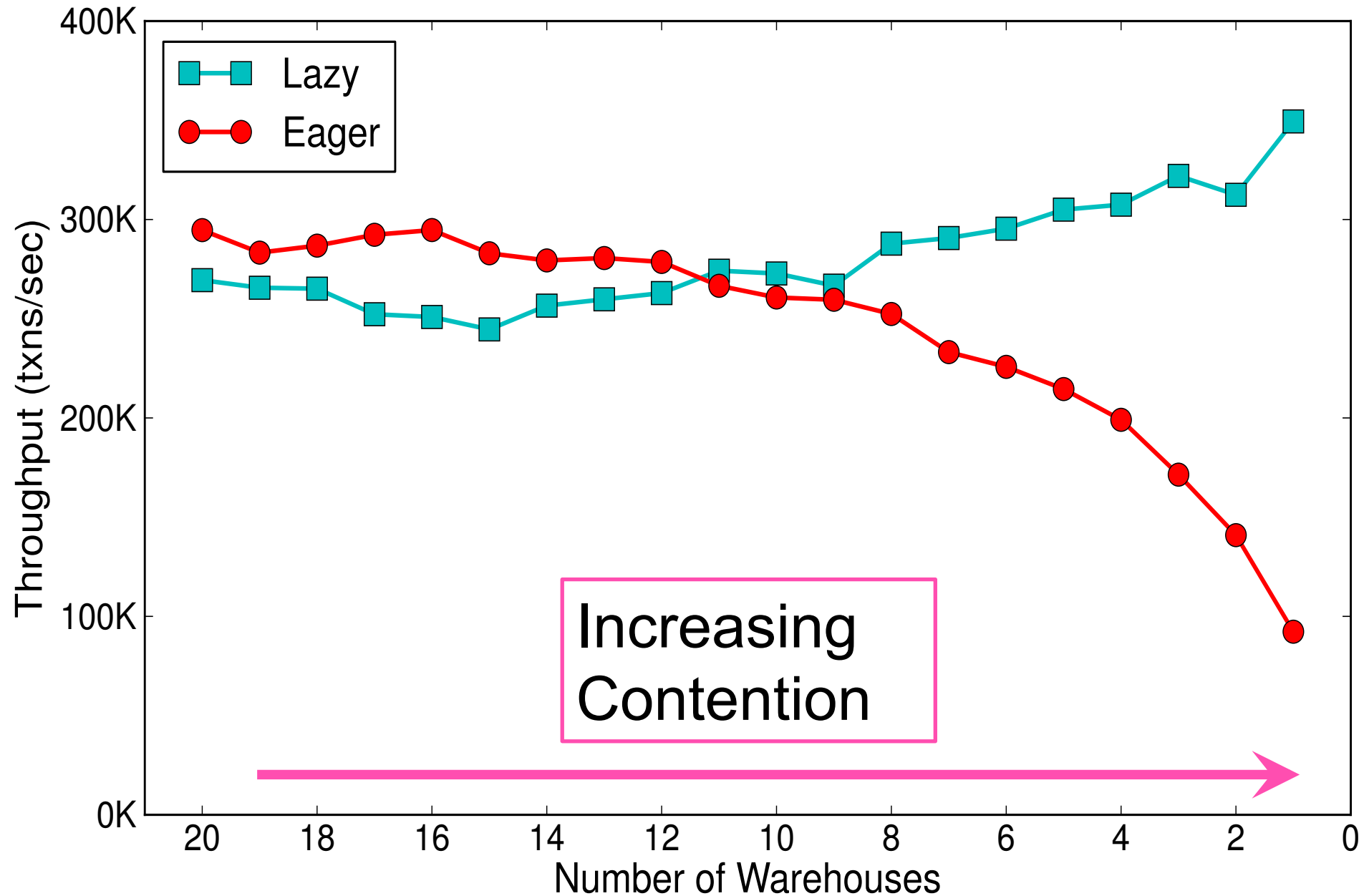
- Lazy and eager systems have comparable throughput

# Temporal Load Balancing

— Input    — Lazy    - - Eager    — Commit Decision



# TPC-C Throughput



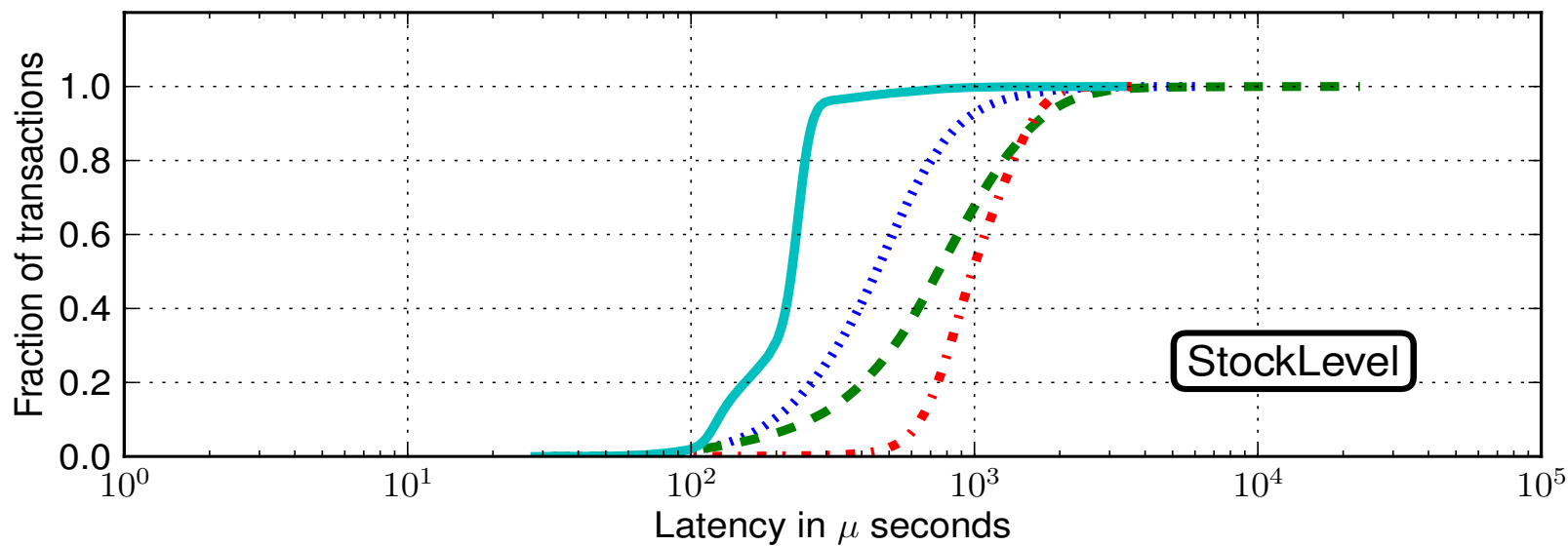
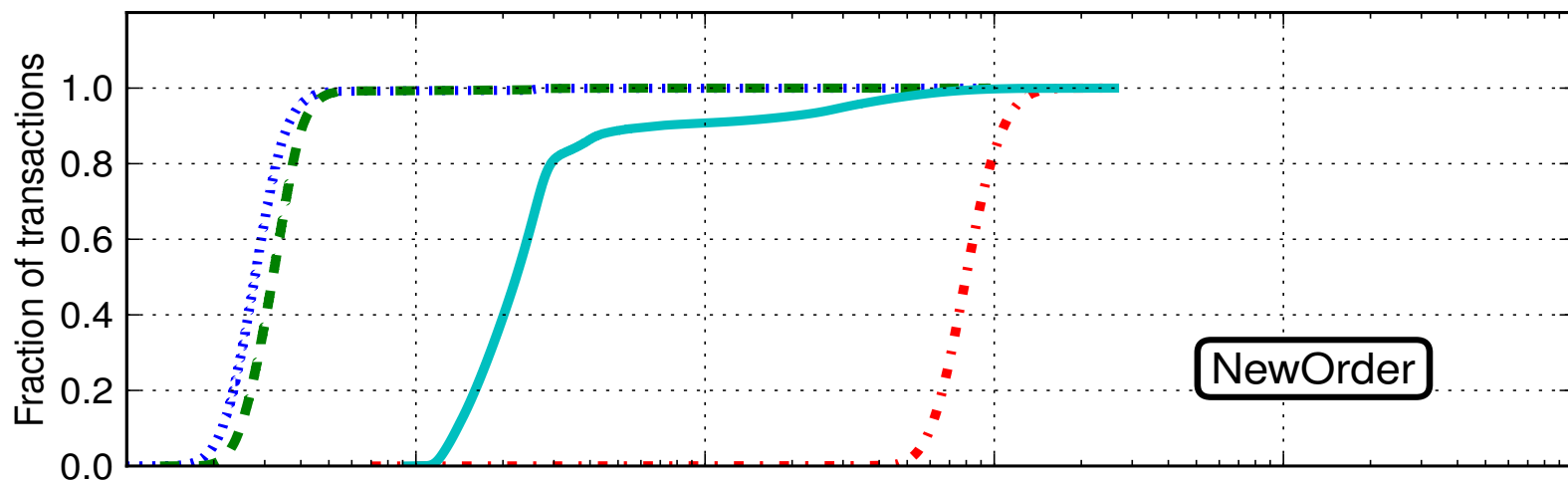
# Conclusions

- Lazily evaluating txns has its benefits
  - Cache Locality
  - Temporal Load Balancing
  - Contention Reduction

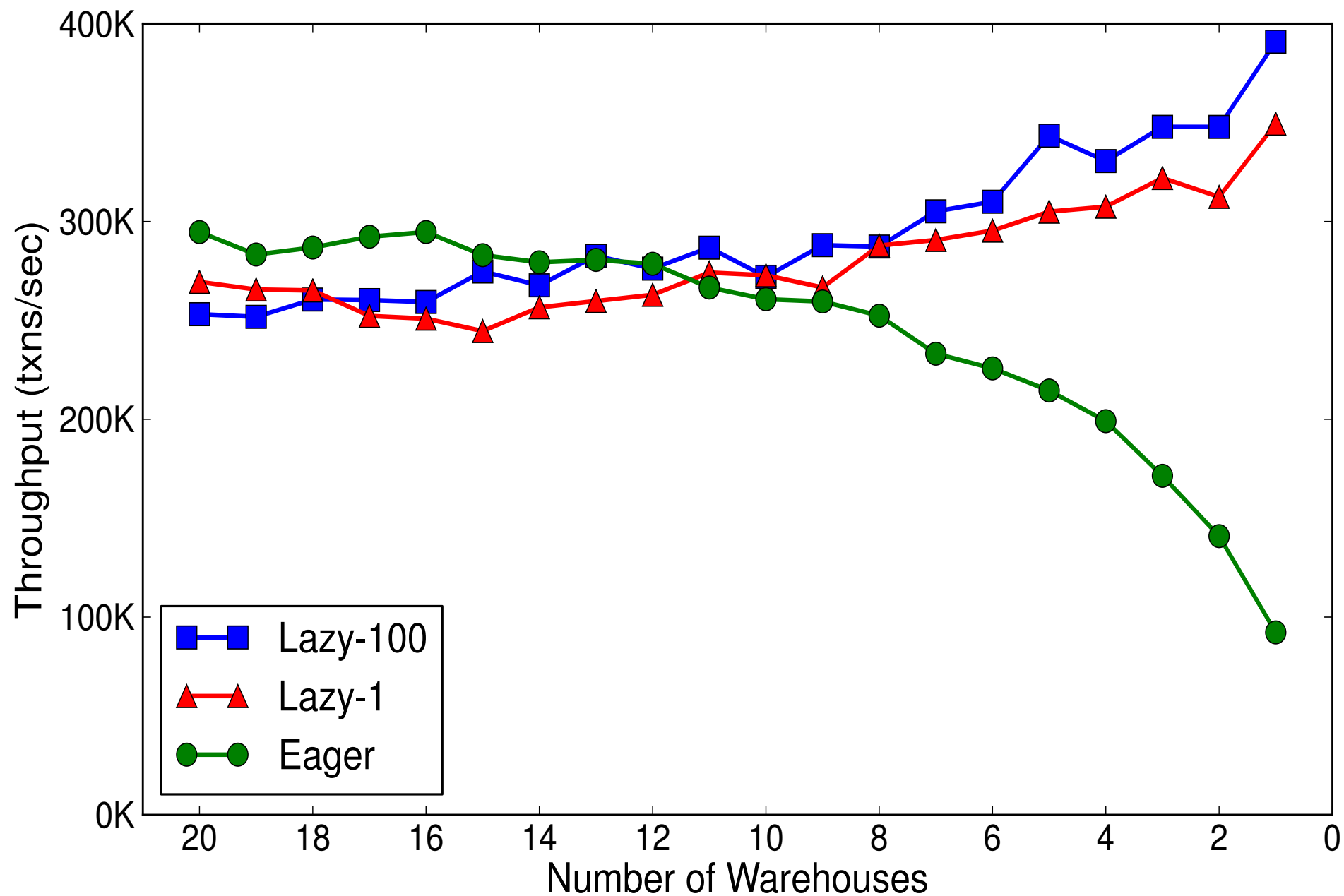
To see the rest of our  
conclusions, read the  
paper

# TPC-C Latency

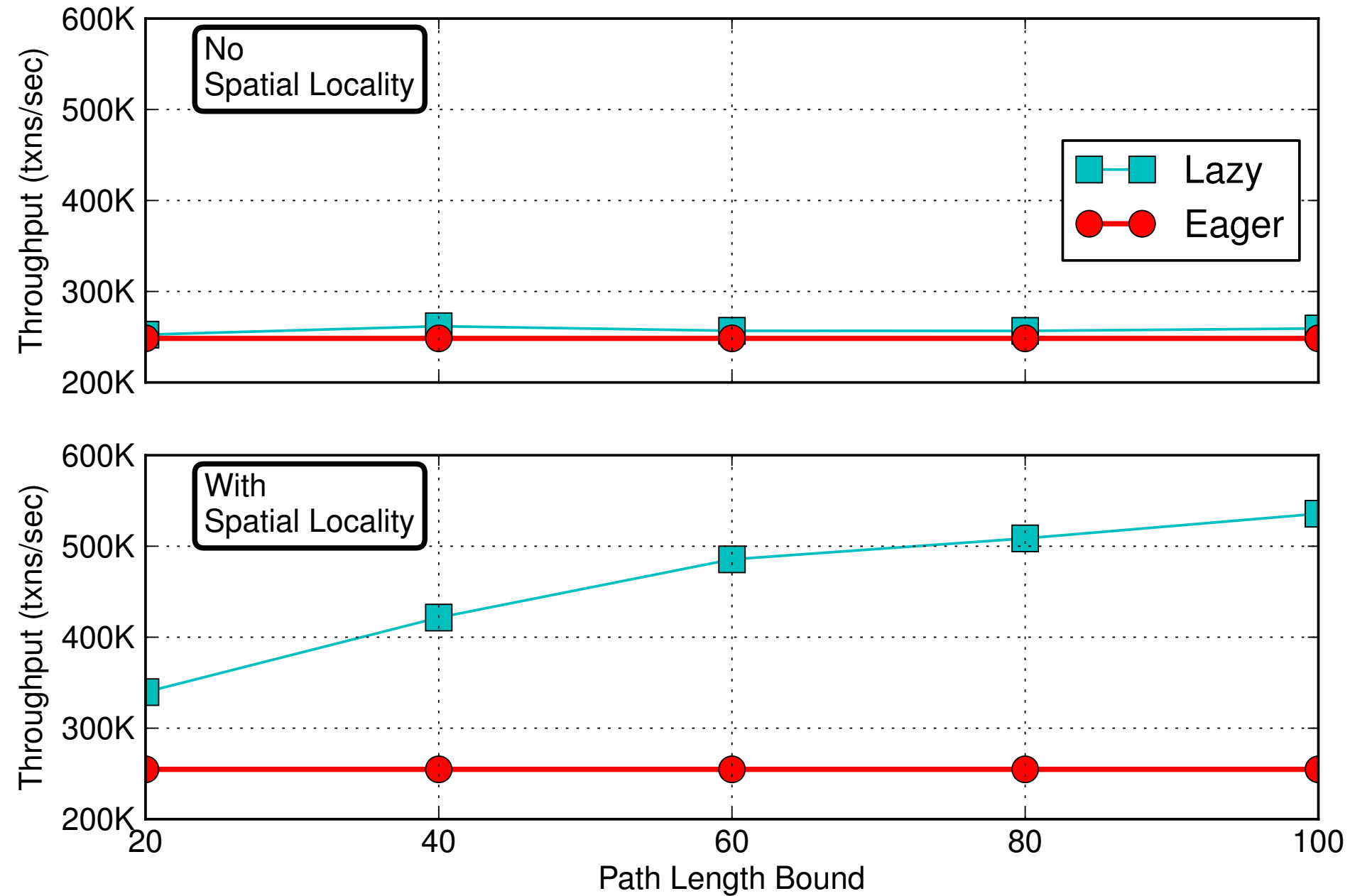
..... Lazy, 1 W      - - - Lazy, 20 W      . . . Eager, 1 W      — Eager, 20 W



# TPC-C Throughput



# Microbenchmark Throughput





# Microbenchmark Latency

Lazy Path 20      Lazy Path 100      Eager  
Lazy Path 60

