An Efficient Software Transactional Memory Using Commit-Time Invalidation

CGO

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Motivation

- Problem
  - TM is not fast enough! (Cascaval et al., 2008)
- Reason
  - Conflict Detection and Opacity
  - Most TMs use ***Validation***
- Our solution:
  - ***Full Invalidation***
  - ***InvalSTM***

TM Performance Bottleneck

- ***Conflict Detection***
  - Determine if transaction can commit
    - (Papadimitrou, "Theory of Database Concurrency Control," 1986)
- ***Opacity***
  - Keep in-flight transactions consistent
    - (Guerraoui & Kapalka, PPoPP'08)

Conflict Detection

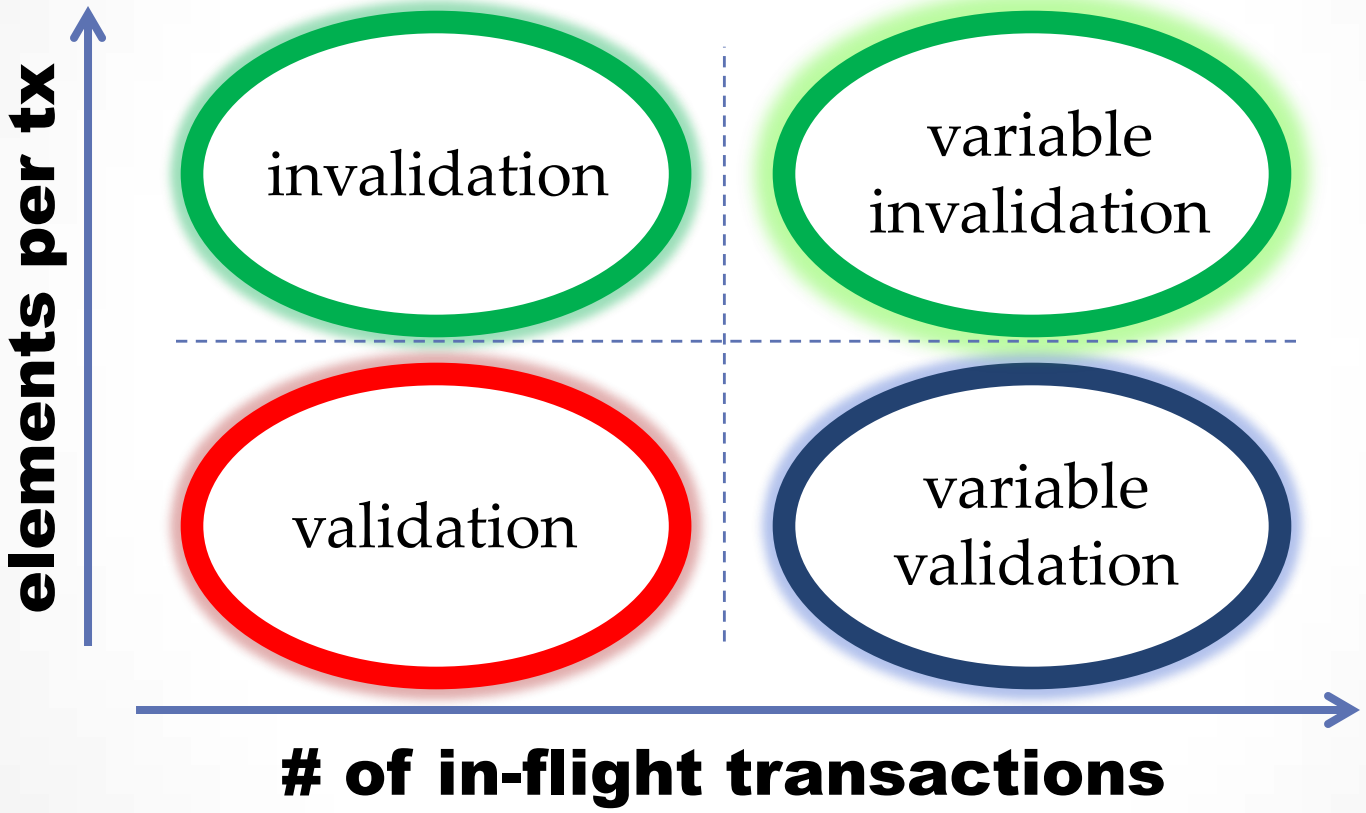
Conflict: $W_{T1} \cap (W_{T2} \cup R_{T2}) \neq \emptyset$

- **Validation** (T2)
  - ***Analyze the Past***
    - Version # is same
- **Invalidation** (T1)
  - ***Analyze the Future***
    - *T2.valid = false*

Opacity

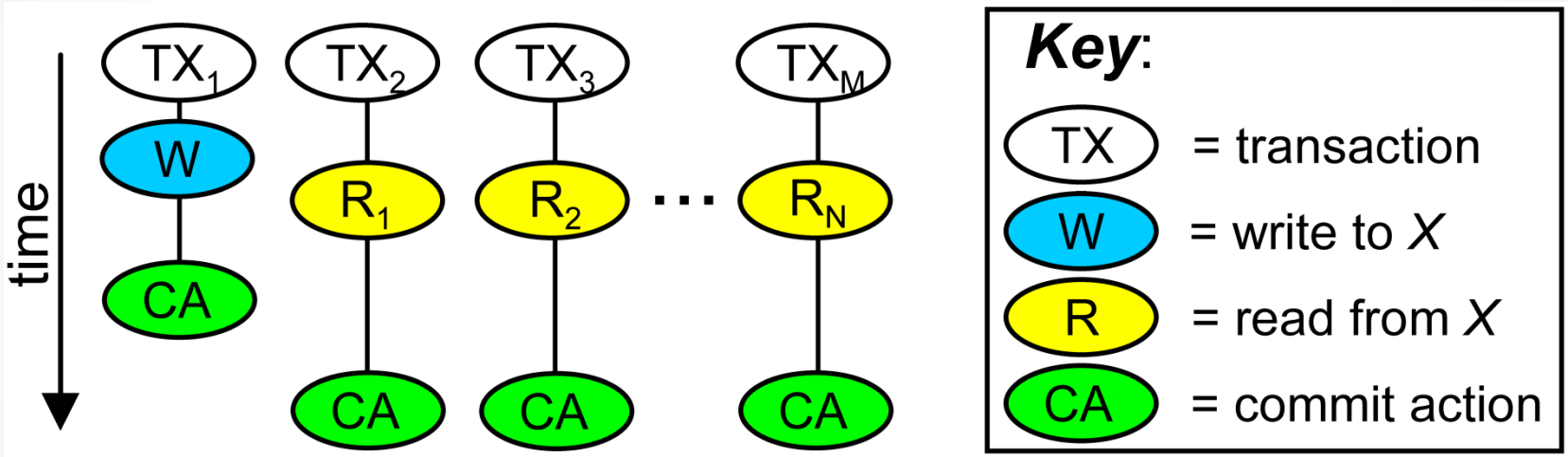
- **Validation**
  - Version # is same
- **Invalidation**
  - **Check *valid != false***

Validation Vs. Invalidation



Contending + Concurrent Workload

1-Writer, N-Reader

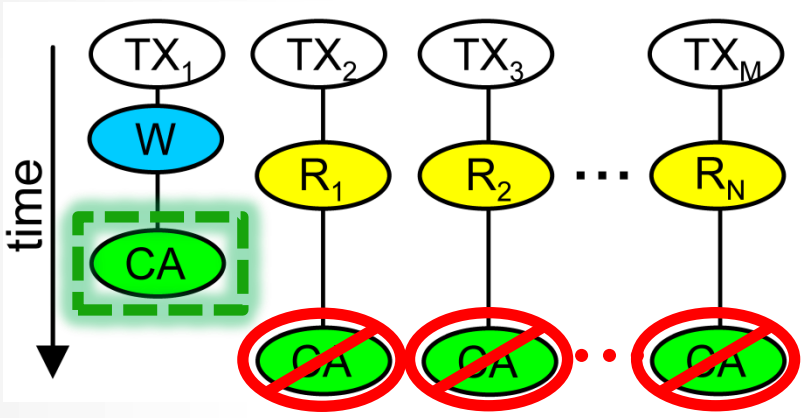


Commit to Executed Ratio: ***Commits / Executed***

Max = 1, Min = 0

Side-By-Side Analysis

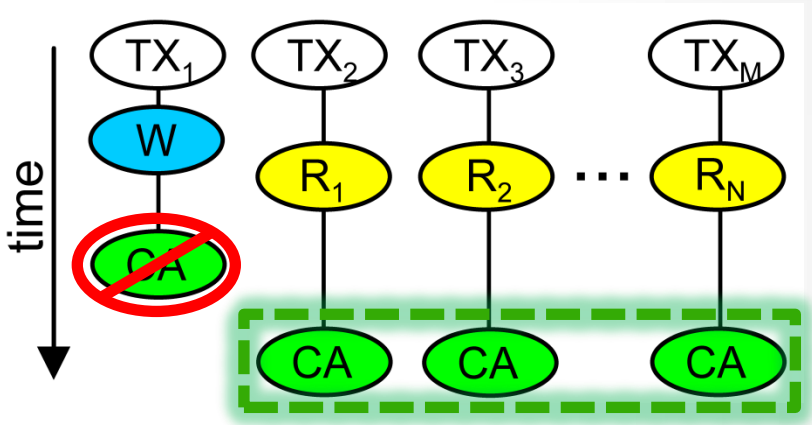
Validation



Commit / Executed: **1 / M**

$$\lim_{M \to \infty} \left(\frac{1}{M} \right) = 0$$

Invalidation



Commit / Executed: **(M-1) / M**

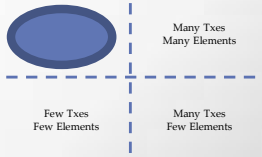
$$\lim_{M \to \infty} \left(\frac{(M-1)}{M} \right) = 1$$

Algorithmic Growth

$$\textit{Validation} = \sum_{i=1}^{M} \sum_{j=1}^{r_i} j$$

$$\textit{Invalidation} = \sum_{i=1}^{M} \left(r_i + \sum_{j=1}^{F_i} w_i \left(s_{rj}(r_j) + s_{wj}(w_j) \right) \right)$$

$$\textit{Bloom Inval} = \sum_{i=1}^{M} (r_i + (2kw * Fi))$$

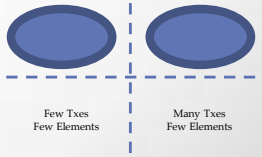


Efficient Read-Only Transactions

$$\textit{Validation Read-Only} = \sum_{i=1}^{M} \sum_{j=1}^{r_i} j$$

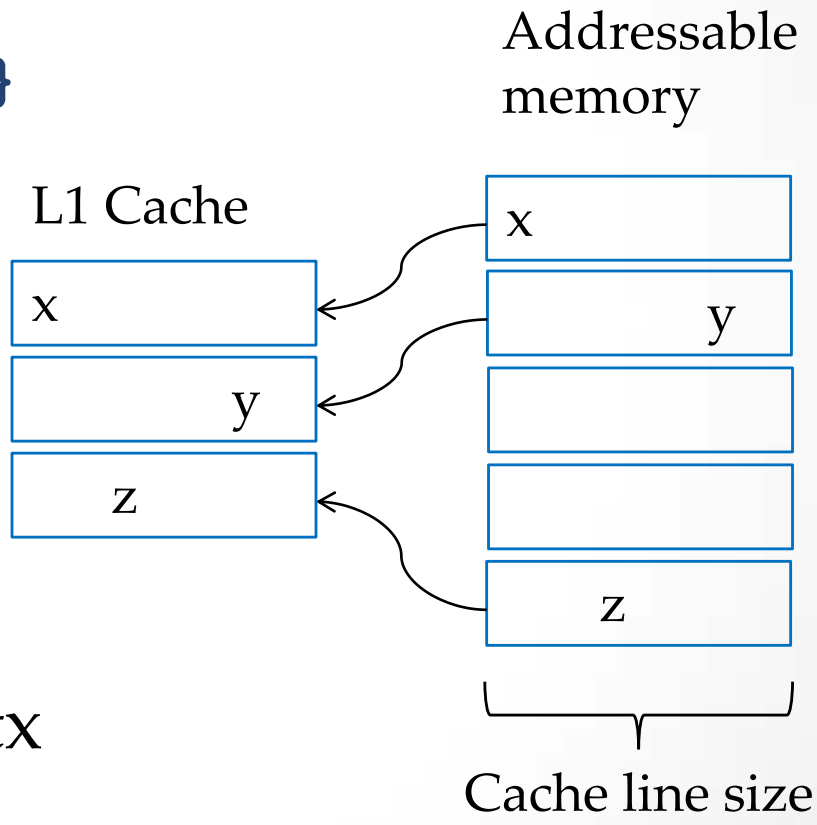
$$\textit{Invalidation} = \sum_{i=1}^{M} \left(r_i + \sum_{j=1}^{F_i} w_i \left(s_{rj}(r_j) + s_{wj}(w_j) \right) \right)$$

$$\textit{Invalidation Read-Only} = \sum_{i=1}^{M} r_i$$



Validation + Memory

```
atomic { x = y / z; }
```

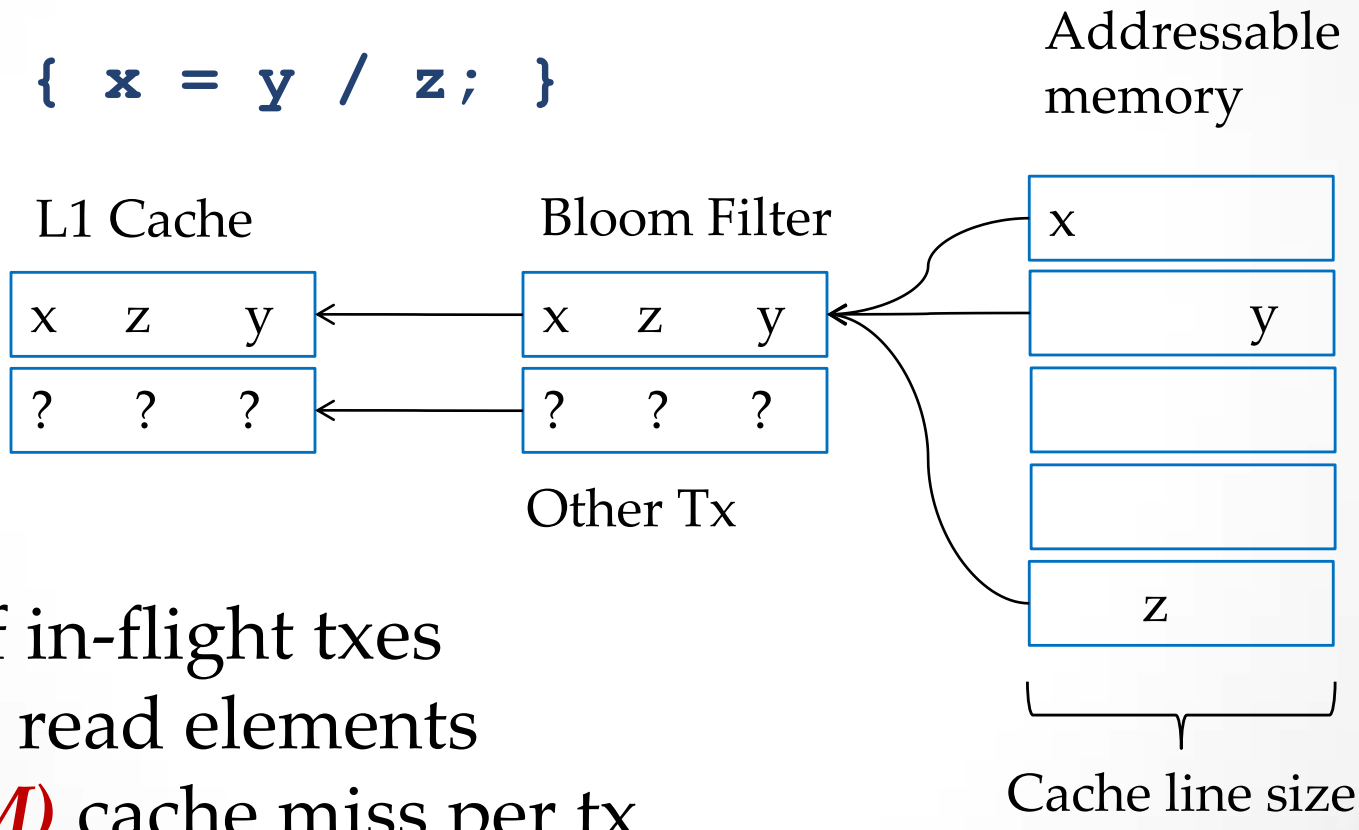


N = Elements per tx

$O(N^2)$ cache misses per tx

Invalidation + Memory

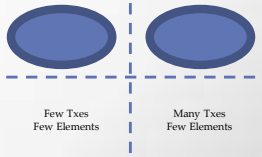
```
atomic { x = y / z; }
```



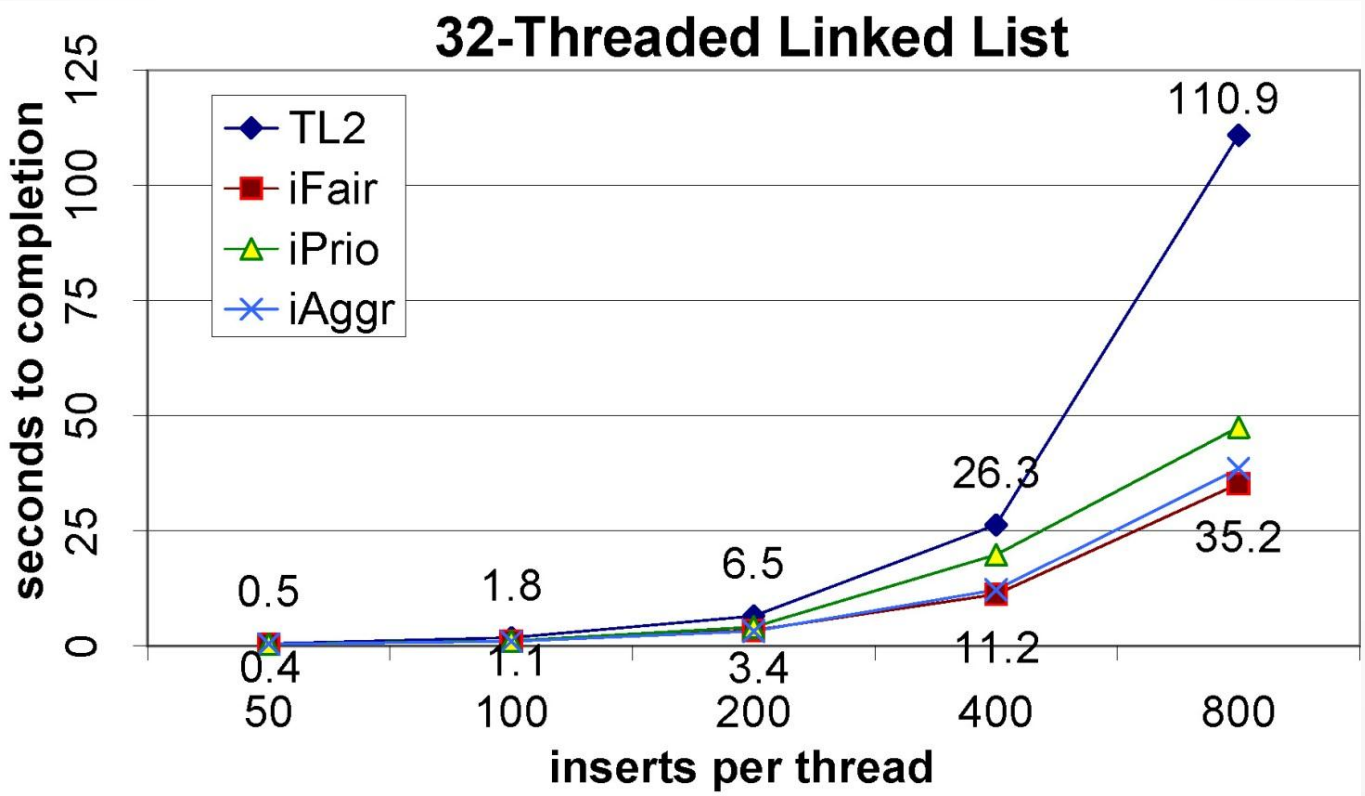
M = # of in-flight txes

N = # of read elements

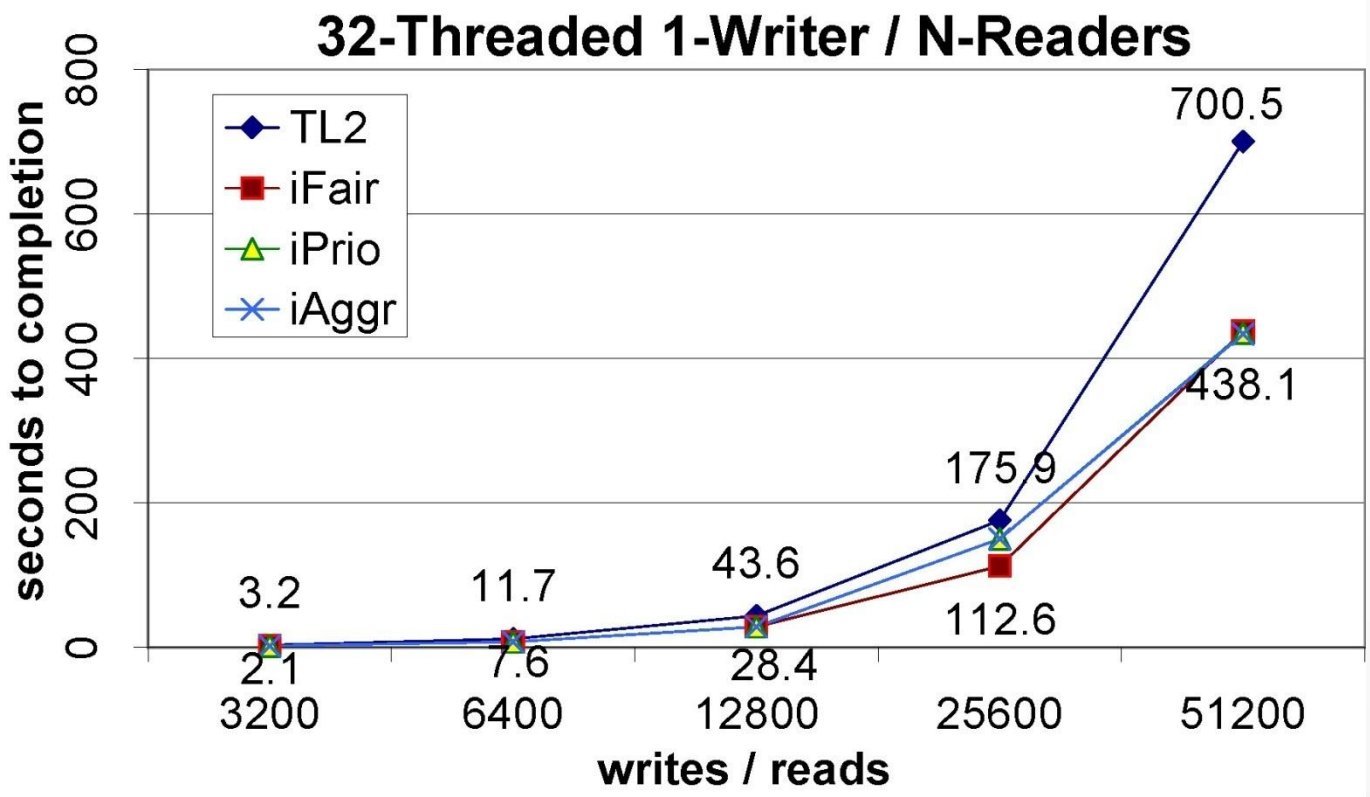
O(N + M) cache miss per tx



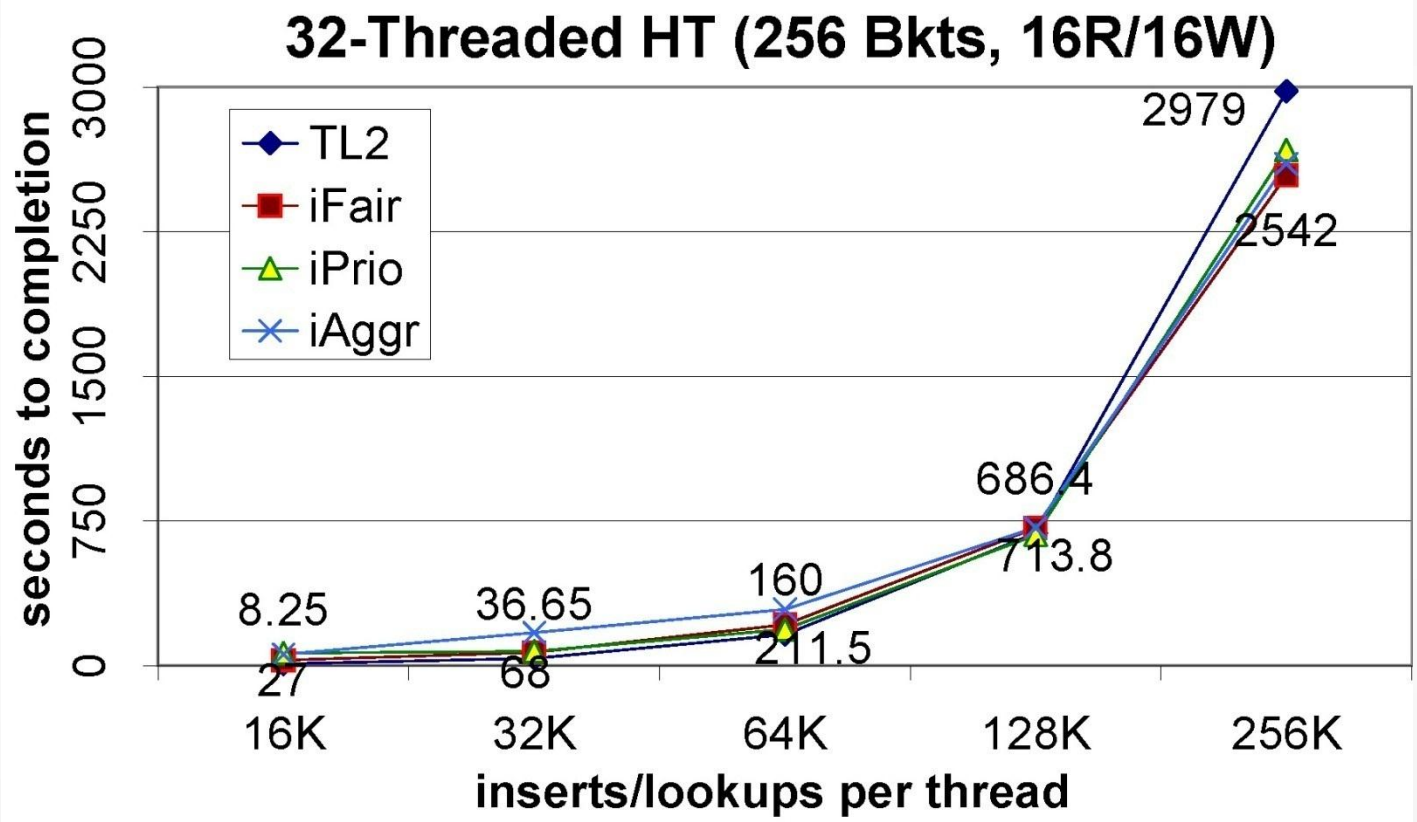
Linked List


32-Threaded Linked List
seconds to completion
0
25
50
75
100
125
TL2
iFair
iPrio
iAggr
0.5
0.4
1.8
1.1
6.5
3.4
26.3
11.2
110.9
35.2
50
100
200
400
800
inserts per thread

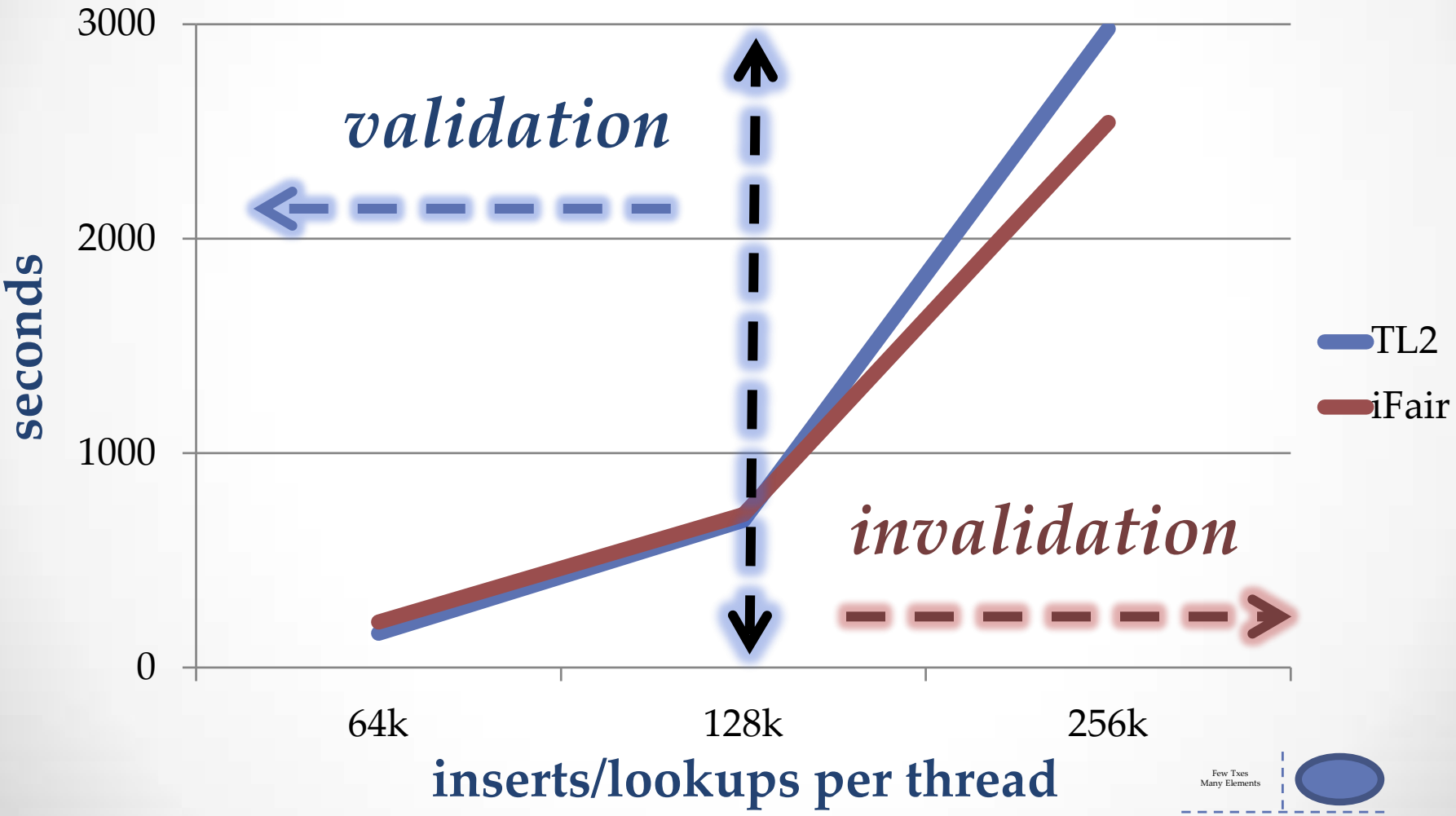
1-Writer / N-Readers



Hash Table

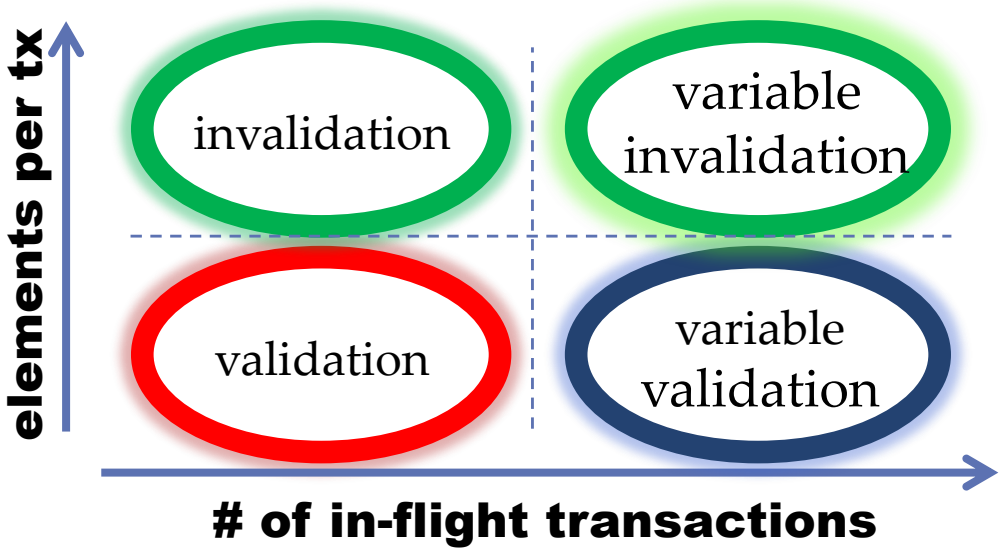

32-Threaded HT (256 Bkts, 16R/16W)
seconds to completion
0
750
1500
2250
3000
TL2
iFair
iPrio
iAggr
2979
2542
686.4
713.8
160
211.5
36.65
68
8.25
27
16K
32K
64K
128K
256K
inserts/lookups per thread

Zoomed Hash Table



Conclusion

- Invalidation (InvalSTM) can be efficient



- Next up
  - Proof of correctness for Full Invalidation
  - InvalSTM + STAMP
- Special thanks to Spear and Herlihy

Questions?

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