Non-Blocking Timeout in Scalable Queue-Based Spin Locks

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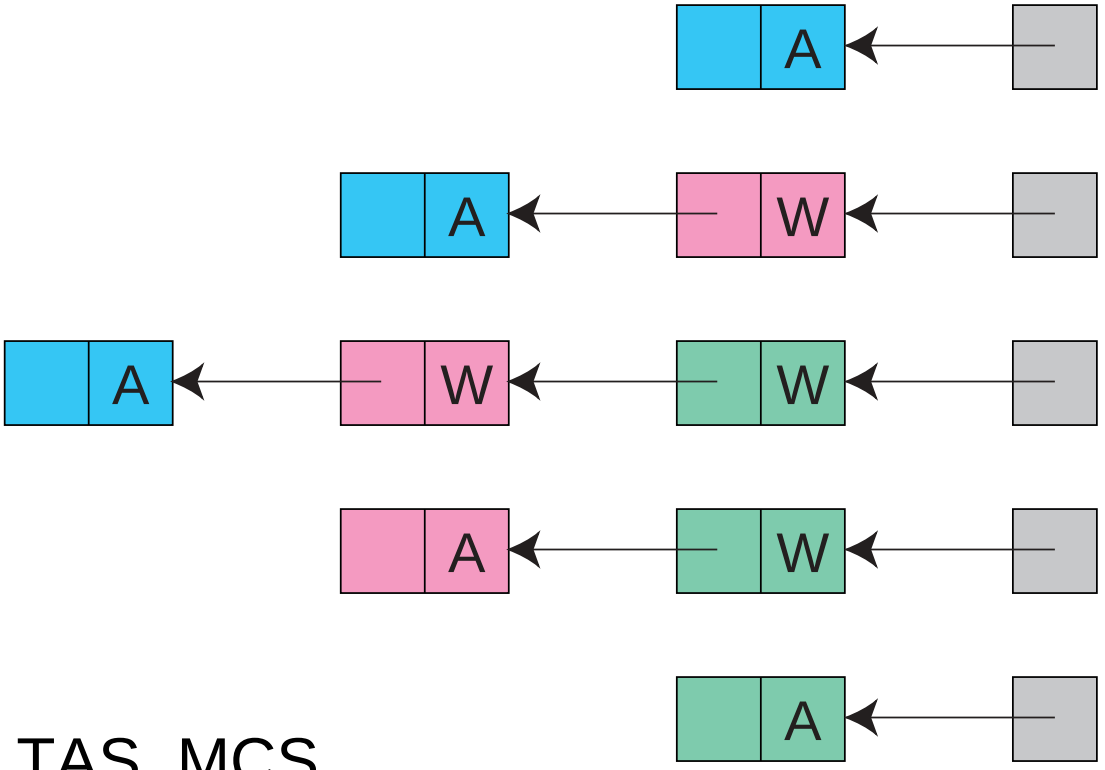
- Motivation: context and problem
- Solution(s) and performance
- Impossibility conjecture

➜ www.cs.rochester.edu/~scott/synchronization

Busy-wait mutual exclusion

- Preferable to rescheduling when
  - » expected wait time is small
  - » nothing else needs the processor
- Widely used in multiprocessor OSes; also some user-level programs
- *Scalability* the traditional problem for OSes and large scientific programs; solved with queue-based locks
- Preemption and deadlock the traditional problems in OLTP and related apps; solved with *timeout*

The CLH queue-based lock



- Cf TAS, MCS
  - » speed, space, coherence

Spin locks with timeout (try-locks)

- Real time: signal error or pursue alternative code path
- OLTP
  - » assume transaction deadlock or preemption of lock holder
  - » abort current transaction
  - » yield processor
- Easy in test-and-set lock, but not in queue-based lock!
  - » must introduce neighbors to each other before leaving

➜ Can we have our cake and eat it too?

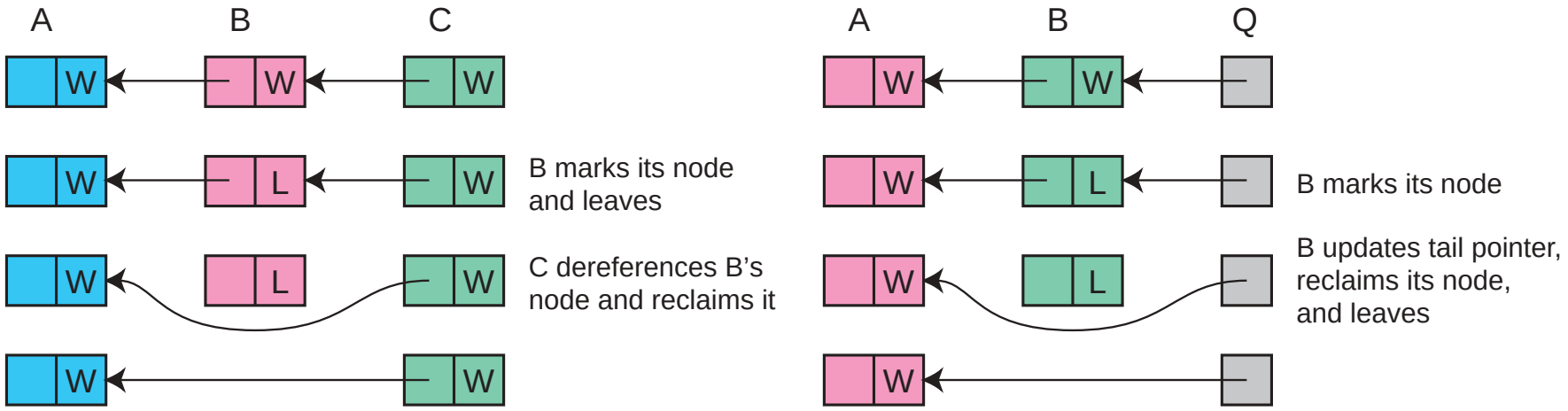
Queue-based try-locks

- PPoPP 2001 [Scott & Scherer]
  - » CLH and MCS try-locks
    - – O(L+T) space
    - – Fine for real-time or for deadlock recovery, but not for preemption recovery: timeout is not non-blocking
- PODC 2002 (current contribution)
  - » CLH-NB and MCS-NB try-locks
    - – Preemption-safe: non-blocking timeout
    - – unbounded space worst case; can be modified to be O(LxT); O(L+T) expected

How to deal with preemption

- Need to be able to leave the queue without waiting for anybody else
- Craig [1993] proposed abandoning queue node, to be reclaimed at head of queue
  - » Unbounded space if theads can re-request same lock; O(LxT) otherwise
- CLH-NB and MCS-NB-try locks
  - » immediate reclamation of abandoned nodes (by successor, not by departing thread, except at tail of list)
  - » Worst-case space same as Craig, but ~(L+T) in practice

CLH-NB-try lock

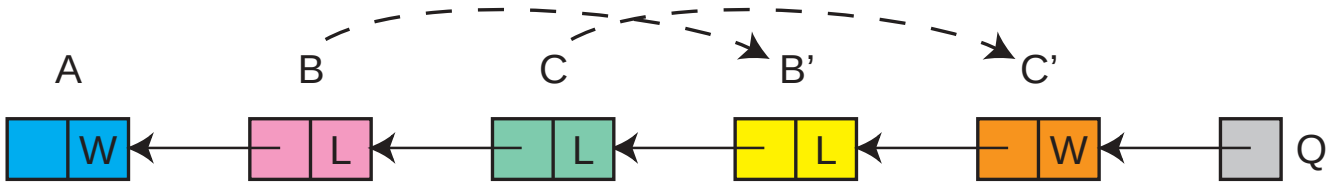


- Reclaim dummy node in similar way in uncontested lock
- Complication: space management
  - » lose "my" node when timing out
  - ➜ need a (lock-free) pool of nodes

Pathological case

- Three threads: A holds lock; initially B and C are waiting
  - » B and C decide to leave; stop spinning on A and B's qnodes
  - » B marks own node; CAS fails; leaves queue; C is preempted
  - » B requests lock again; gets in line with new node; times out; decides to leave; stops spinning on C's node
  - » C wakes up; marks own node; CAS fails; leaves queue; B is preempted

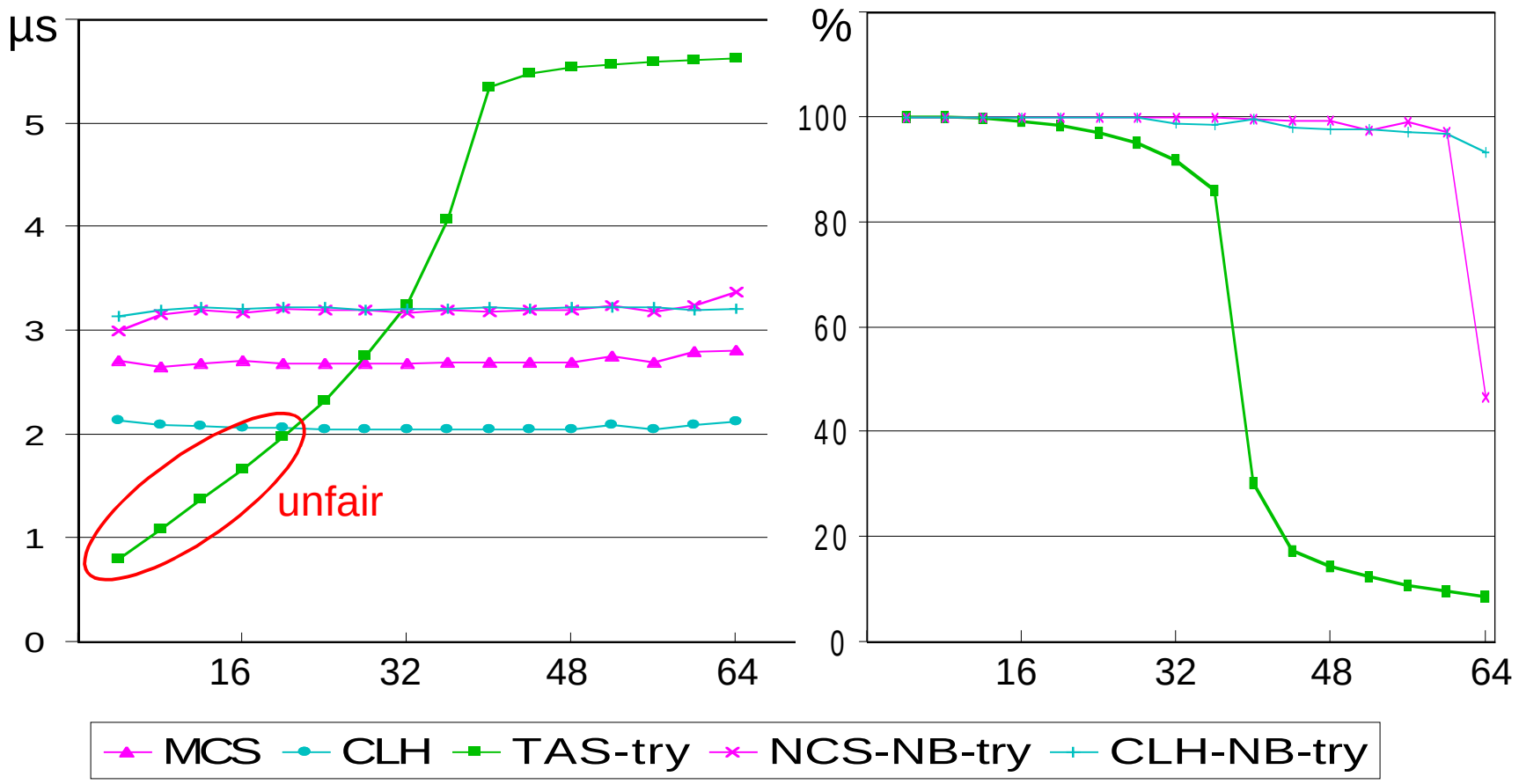
  repeat
- Unbounded space worst case; O(TxL) if threads never re-try same lock, or re-use node if they do



Thanks to Victor Luchangco of Sun Labs

Multiprocessor lock-passing time (466MHz E10K)

- 225µs patience; 229ns critical, 440ns non-critical work

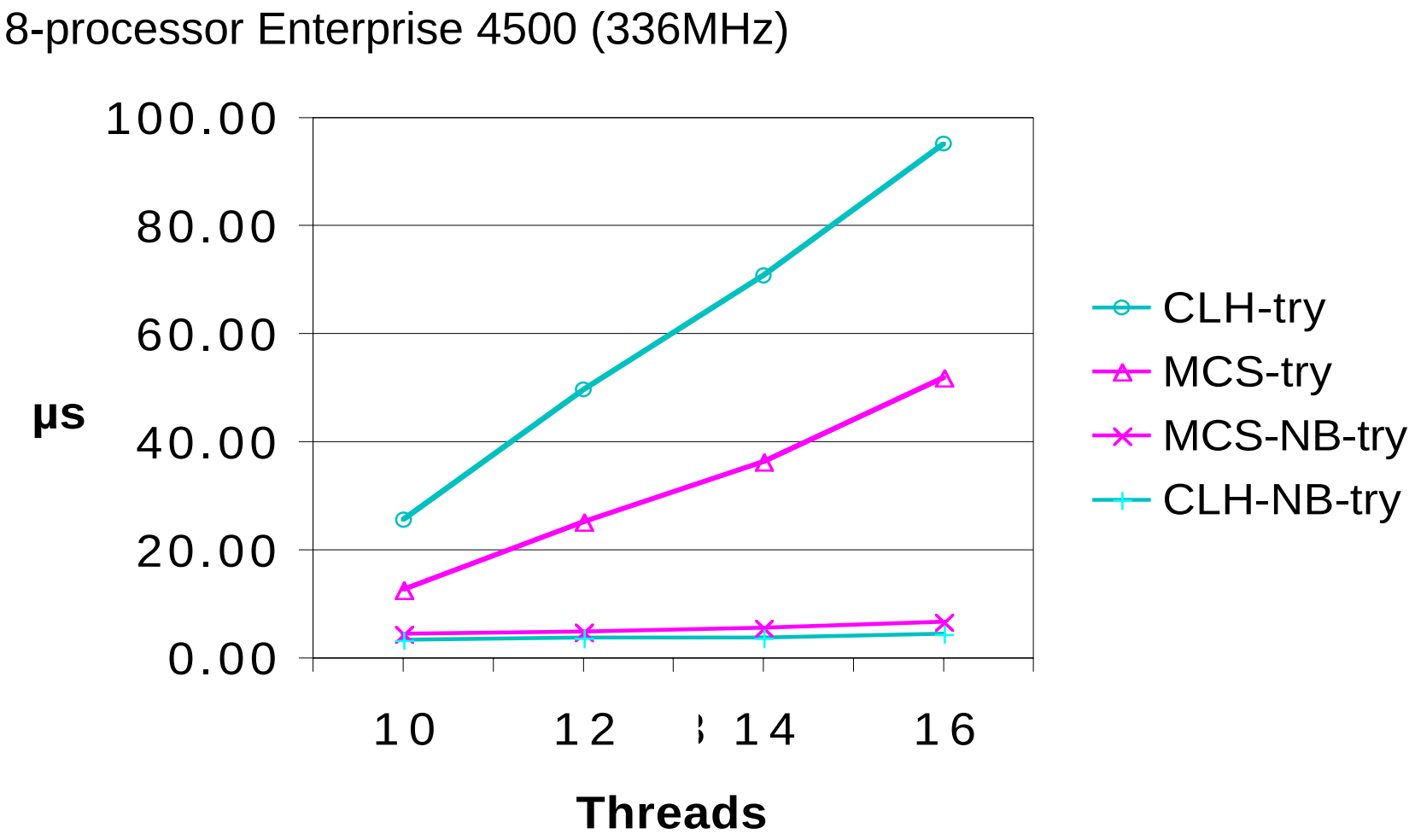


Modeling time-out time

$$
\begin{aligned}
T_s &= \frac{ti}{m-1}[T_l + (1-s)(T_p + T_h) + sT_w] \\
&\leq \frac{ti}{m-1}[T_l + T_p + (1-s)T_h] \\
T_h &\geq \frac{(m-1)T_s}{(1-s)ti} - \frac{T_l + T_p}{1-s}
\end{aligned}
$$

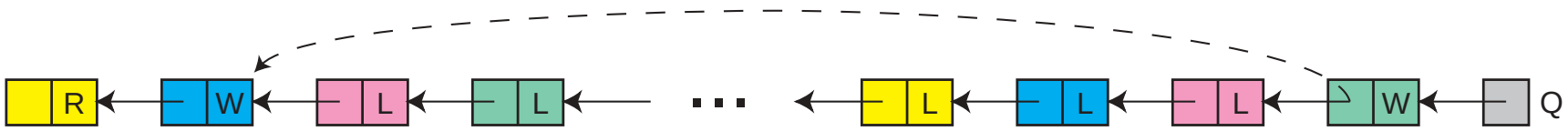
- t threads
- i # loop iterations
- m processors
- s acquire success rate
- T_s wall clock time
- T_p patience
- T_l loop overhead
- T_w average lock wait time
- T_h timeout/handshake time

Time-out time from model



Impossibility conjecture

- Cannot guarantee O(L+T) space with queue and non-blocking timeout:
  - » Imagine N threads waiting in line
  - » Middle N-2 decide (simultaneously) to leave
  - » Need to link the edges together in order to reclaim space
  - » Cannot do it in constant time!



Conclusions

- Contention matters, more now than ever.
- Scalability and timeout are compatible.
  - » Potentially significant benefit for important commercial applications
- Synchronization is still an open problem :-)

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