Distributed Computing and Systems

Chalmers university of technology

Optimistic Synchronization in parallell systems

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Synchronization

synchronization *n.*

1: the relation that exists when things occur at the same time;

2: an adjustment that causes something to occur or recur in unison

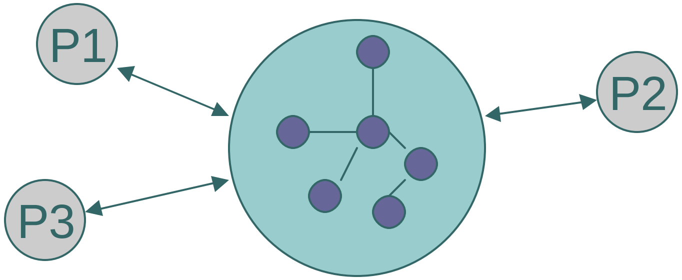
3: coordinating by causing to indicate the same time; "the synchronization of their watches was an important preliminary“

Source: WordNet (1997 Princeton University)

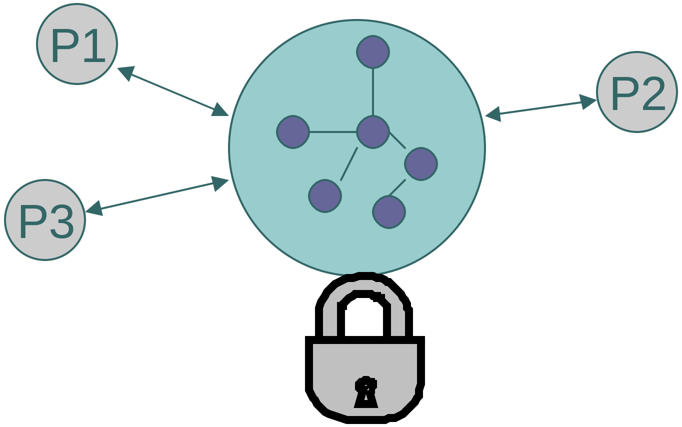
This slide is borrowed from Håkan Sundell

Synchronization

- Shared data structures needs synchronization

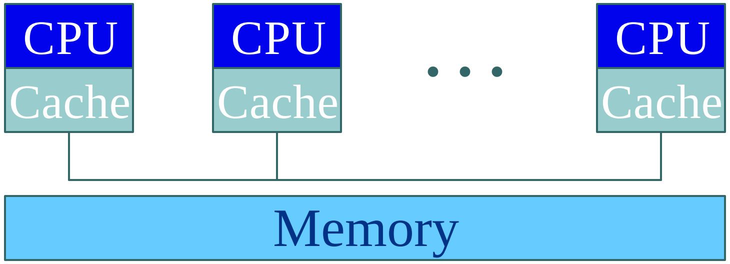


- Synchronization using Locks
  - Mutually exclusive access to whole or parts of the data structure

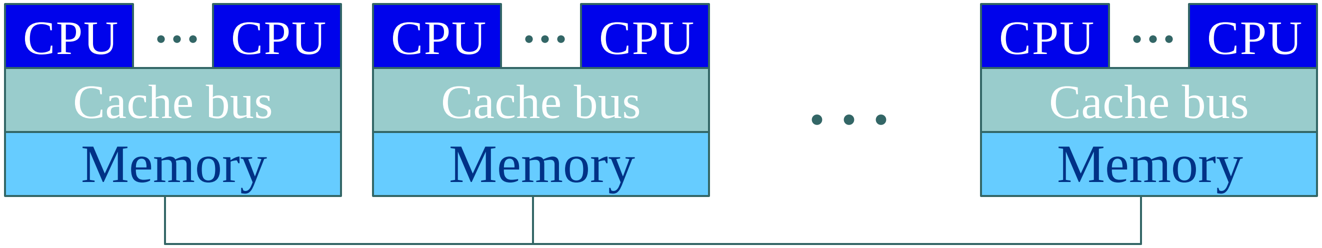


This slide is borrowed from Håkan Sundell

Shared memory Multiprocessor Systems



- Uniform Memory Access (UMA)



- Non-Uniform Memory Access (NUMA)

Blocking synchronization

- Mutual exclusion locks
  - Traditional solution
    - Semaphores, spin-locks, disabling interrupts
    - Protects a critical section
  - Drawbacks
    - Blocking
    - Lock convoys
    - Priority inversion
    - Risk of dead-lock
    - Limits parallelism

Hardware support for synchronization

- Synchronization primitives
  - Built into CPU and memory system
  - Atomic (i.e. a critical section of one instruction)
  - Examples
    - Test-and-set
    - Compare-and-Swap

```
bool compare_and_swap(int *target, int old, int new) atomic {
    if (*target = old) {
        *target = new;
        return TRUE;
    }
    return FALSE;
}
```

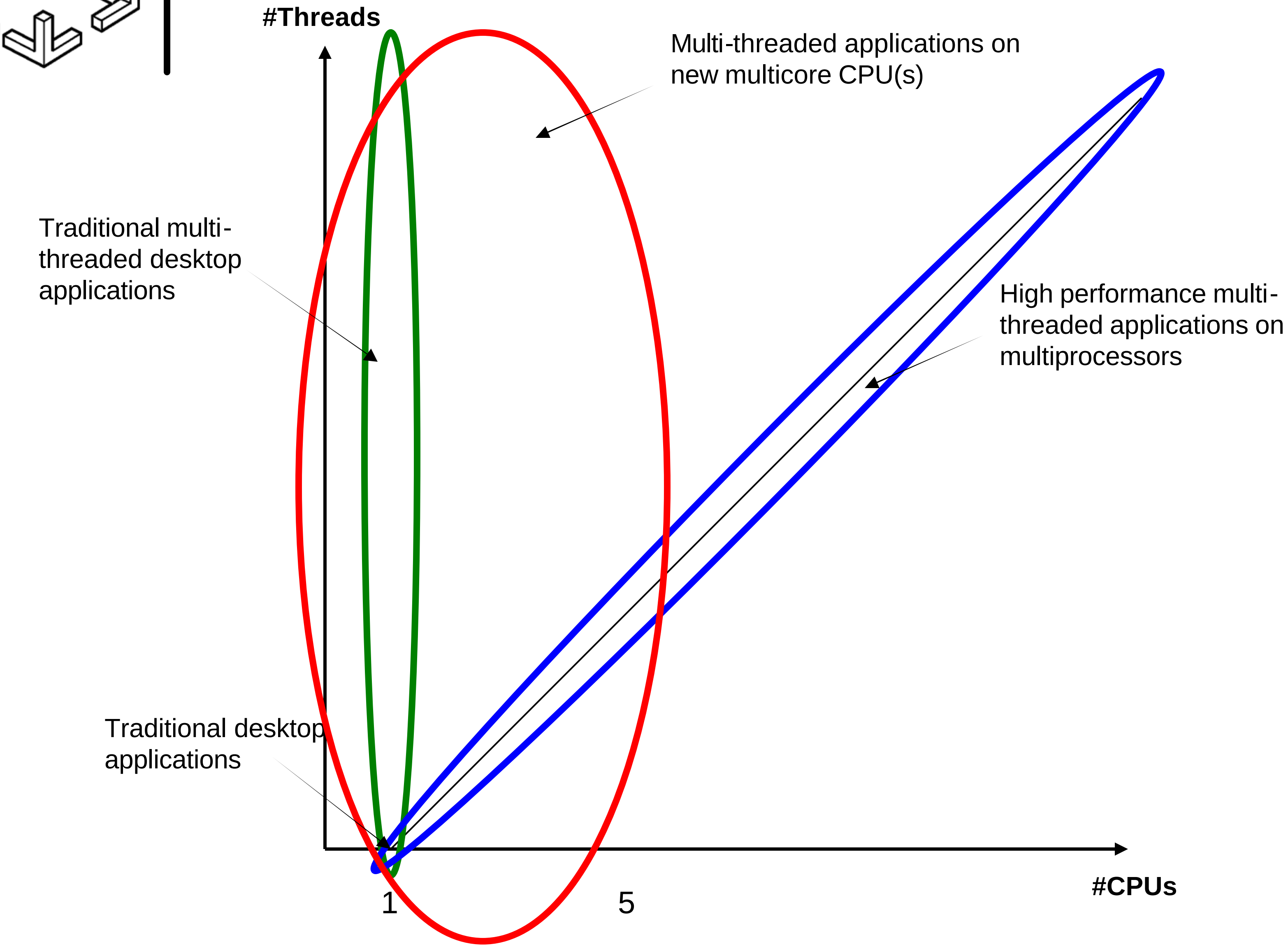
Non-blocking synchronization

- Lock-Free or Optimistic synchronization
  - Try to do the operation as if there where no interference
    1. Prepare update of shared data
    2. Commit using atomic synchronization primitives
    3. Retry if interfered with
  - At least one concurrent operation always makes progress
  - Benefits
    - Fast on average
  - Drawbacks
    - Operations can starve

Non-blocking synchronization

- Wait-Free synchronization
  - All operations finishes in a finite number of their own steps
  - Benefits
    - Bounded execution times
    - Attractive for real-time systems (WCET known, no blocking)
  - Drawbacks
    - Algorithms and implementations usually complex
    - Average performance may be worse than lock-free

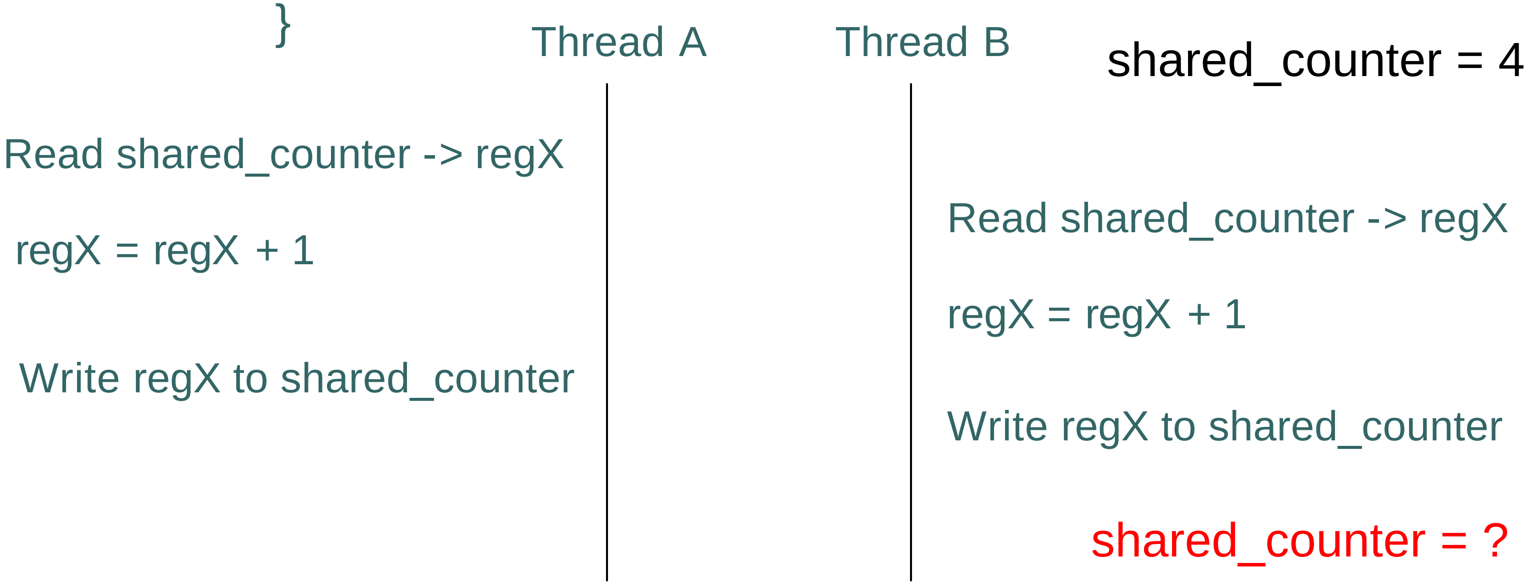
Concurrent applications



#Threads
Multi-threaded applications on new multicore CPU(s)
Traditional multi-threaded desktop applications
High performance multi-threaded applications on multiprocessors
Traditional desktop applications
1
5
#CPUs

Example: Counting (I)

```
volatile int shared_counter = 0;
void count_thread() {
  for (int j = 0; j < MAX; j++) {
    shared_counter = shared_counter + 1;
  }
}
```



Thread A

Thread B

shared_counter = 4

Read shared_counter -> regX

regX = regX + 1

Write regX to shared_counter

Read shared_counter -> regX

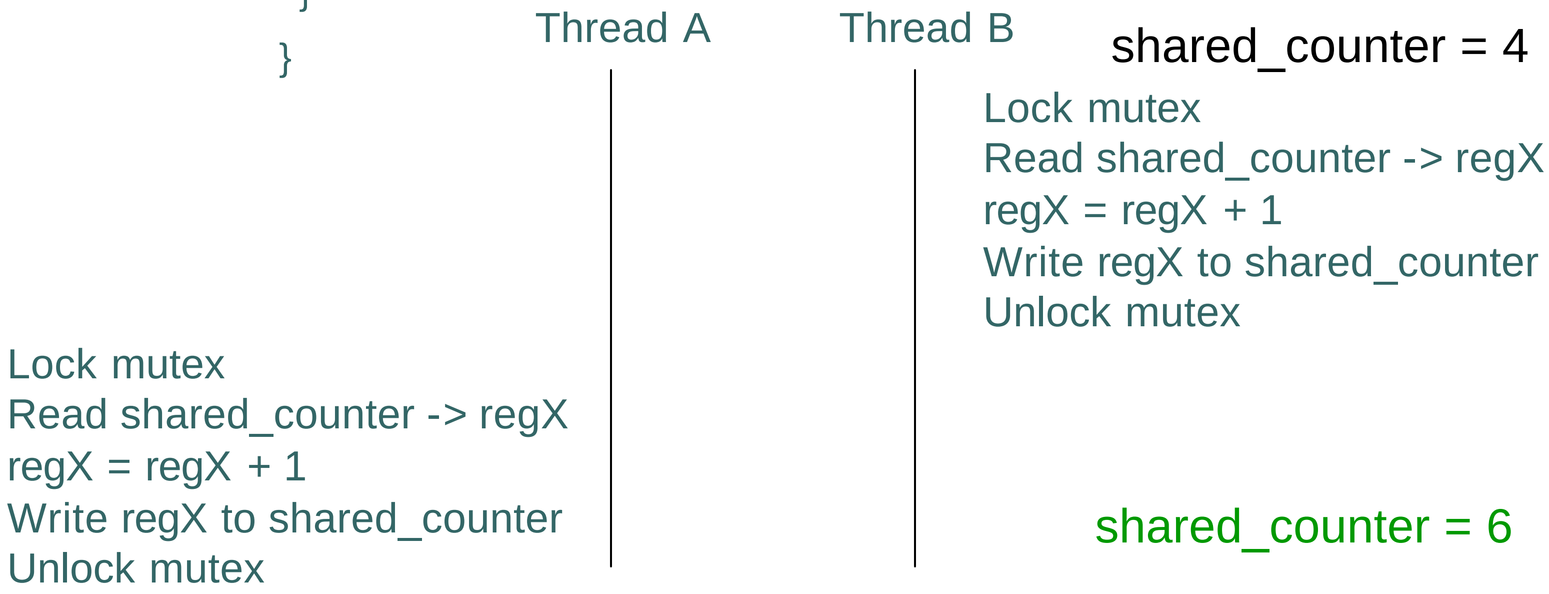
regX = regX + 1

Write regX to shared_counter

shared_counter = ?

Example: Counting (II)

```
volatile int shared_counter = 0;        mutex_t mutex;
void count_thread() {
  for (int j = 0; j < MAX; j++) {
    lock(mutex);
    shared_counter = shared_counter + 1;
    unlock(mutex)
  }
}
```



Thread A

Thread B

shared_counter = 4

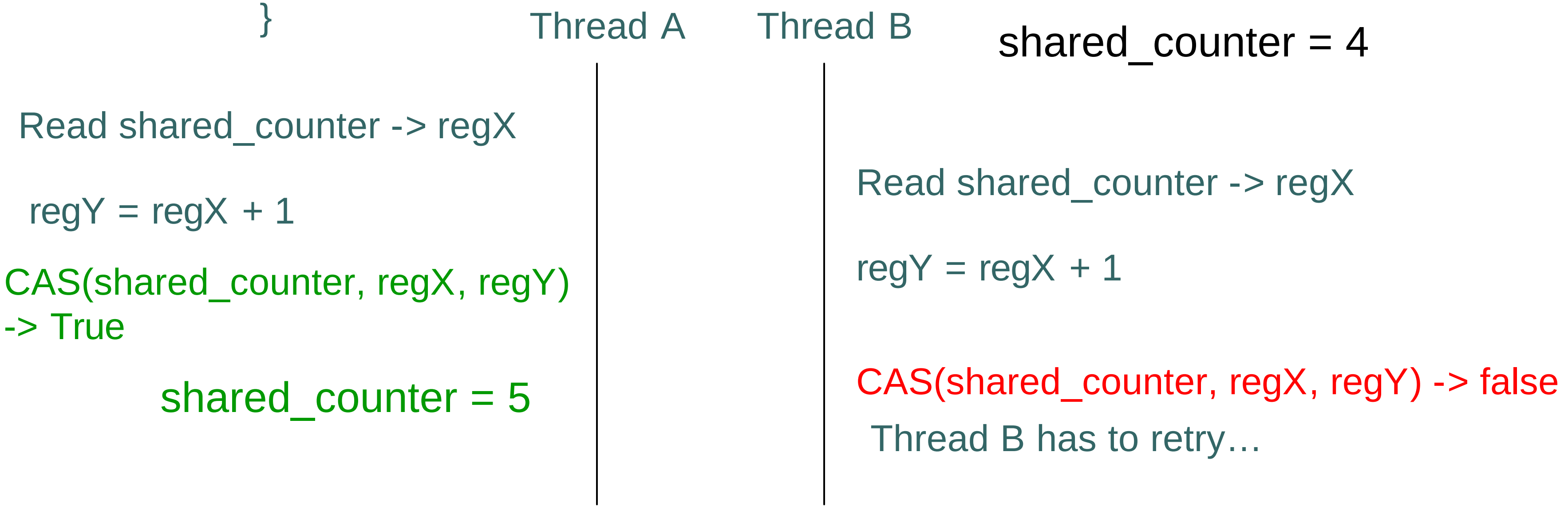
Lock mutex
Read shared_counter -> regX
regX = regX + 1
Write regX to shared_counter
Unlock mutex

Lock mutex
Read shared_counter -> regX
regX = regX + 1
Write regX to shared_counter
Unlock mutex

shared_counter = 6

Example: Counting (III)

```
volatile int shared_counter = 0;
void count_thread() {
  for (int j = 0; j < MAX; j++) {
    repeat {
      int old = shared_counter;
      int new = old + 1;
    } until CAS(&shared_counter, old, new)
  }
}
```



Thread A

Thread B

shared_counter = 4

Read shared_counter -> regX

regY = regX + 1

CAS(shared_counter, regX, regY) -> True

shared_counter = 5

Read shared_counter -> regX

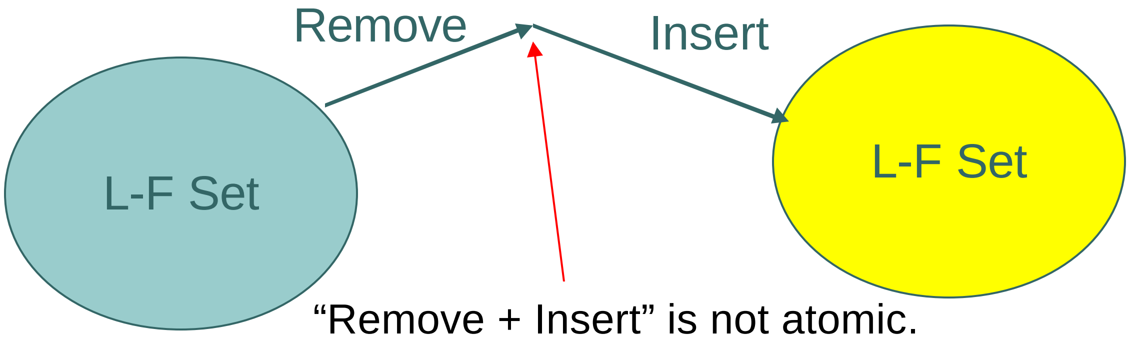
regY = regX + 1

CAS(shared_counter, regX, regY) -> false

Thread B has to retry…

Work in progress

- Combining lock-free operations and structures



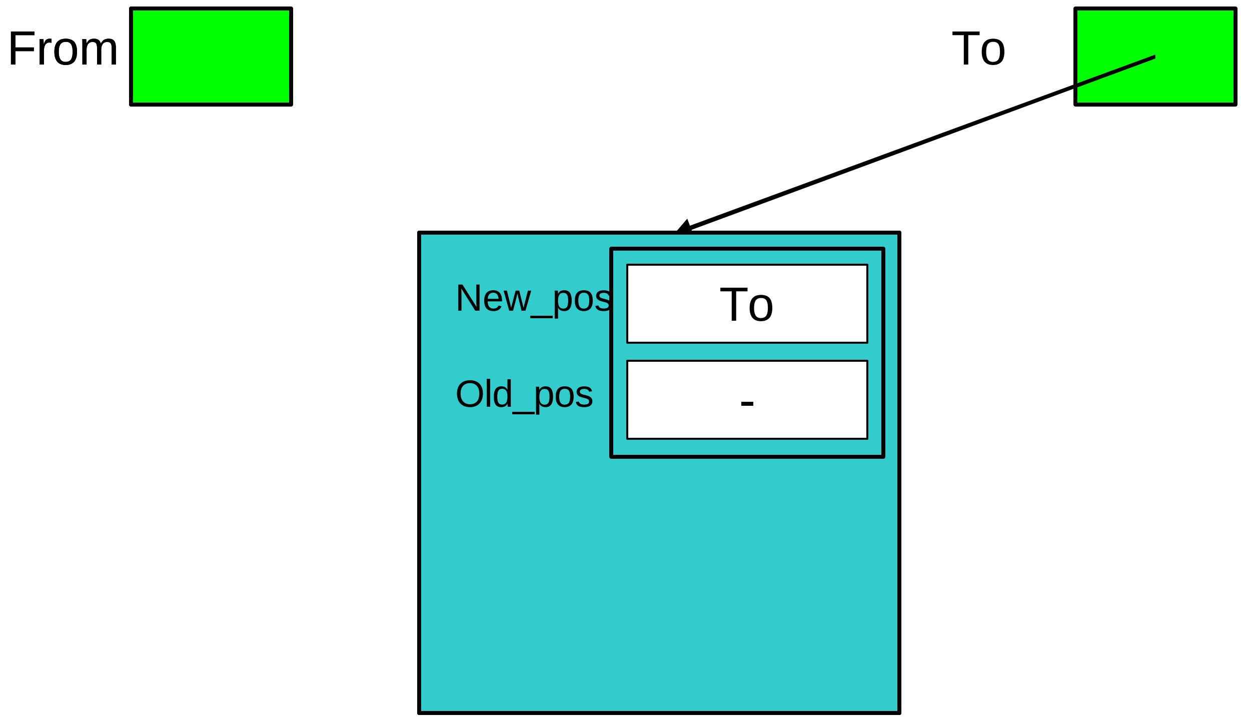
"Remove + Insert" is not atomic.
An item may get stuck in "limbo".

- Case study: Lock-free memory allocator

Moving a shared pointer

- Goal:
  - Move a pointer value between two shared pointer locations
- Requirements
  - The pointer target must stay accessible
  - The same # of shared pointers to the target after the move as before
  - Lock-free behaviour
- Issues
  - One atomic CAS is not enough! We’ll need several steps.
  - Interfering threads need to *help* unfinished operations

Moving a shared pointer



Note that some tricky details are needed to prevent ABA problems..

Summary

- Non-blocking synchronization
  - Can offer increased performance
  - Avoids
    - Blocking
    - Deadlock
    - Priority inversion

Questions?

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