Concurrent Libraries with Foresight

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Nadja Müller

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Contents

Problem Statement

The aim is to extend a linearizable library to allow clients to perform an arbitrary composite operation that appears to execute atomically.

A composite operation is a sequence of library operations.

A linearizable library provides operations that appear to execute atomically.

Correction Condition for Concurrency Control

- Serializable execution

  A serializable execution of two threads is one that is equivalent to either thread T1 executing completely before T2 executes or vice versa.
- No deadlocks
- No rollbacks

Example Library Maps

```
Class Maps {
    int createNewMap();
    int put (int mapId, int k, int v);
    int get(int mapId, int k);
    int remove(int mapId, int k);
    bool isEmpty (int mapId);
    int size (int mapId);
}
```

Contents

Clients

- Multiple threads
  - Statements changing only thread-local state
  - Statements that invoke a library operation
- No shared state except the state of the library
- Follows the client protocol

Client Protocol

Provide foresight information provided mayUse operations:

- stand for set of library functions the client may use
- The Client must have called the appropriate mayUse function before executing a library function
- The declared set should only shrink as the execution proceeds

Example:

- mayUseAll(): CreateNewMap, put, get, remove, isEmpty, size
- mayUseMap(int m): put, get, remove, isEmpty, size on map m
- mayUseKey(int m, int k): put, get, remove on map m with key k
- mayUseNone(): no library Operation

Example

```
If (get(m,x) == get(m,y){
        remove(m,x);
Else{
        remove(m,x);
        remove(m,y);
}
```

Example

```
If (get(m,x) == get(m,y){
        remove(m,x); mayUseNone();
Else{
        remove(m,x);
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Example

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mayUseMap(m);
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Else{
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         mayUseKey(m,y); remove(m,y); mayUseNone();
}
```

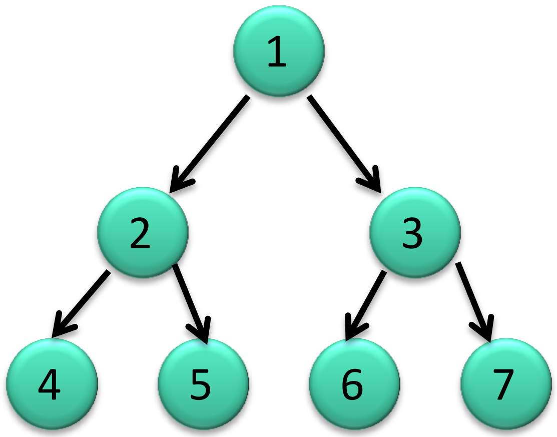
Library

- The Library is extended with additional procedures, which are used for synchronizaion.

- The Extension should have the following poperties:
    - Progress
    - If the client follows the Client Protocol and is completable, then every execution is completable and serializable

Library Extension Implementation

- Translate semantic properties into Tree Structure
  - Every child allows a subset of library operations of its parent
  - Different parameterization allows finer granularity
- MayUse functions follow the Locking Algorithm and make sure no child is locked before proceeding



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Locking Algorithm

First invocation of a mayUse operation m, locking node P(m):

- Obtain a lock of the root
- Follow the path in the tree, locking each node in the path including P(m)
- Unlock all nodes except P(m)

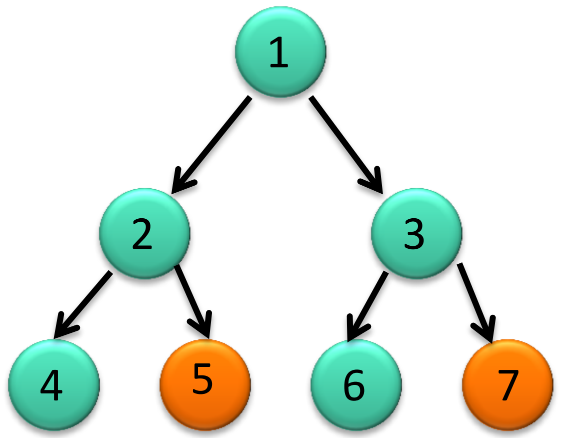
Invocation of a mayUse operation m’ by a thread holding the lock on P(m):

- Lock all nodes in path from P(m) to P(m’)

Invocation of mayUseNone():

- Release all locks

Example



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- mayUseMap(1);

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If (get(1,1) == get(1,1){
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        mayUseNone();
}
```

Turquis:	Unlocked
Orange:	Locked by another thread
Red:	Locked by own thread

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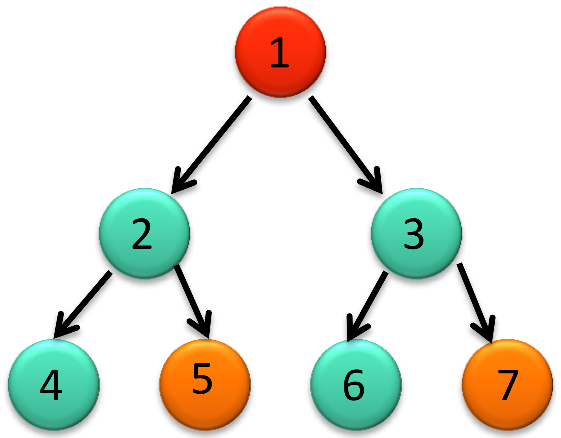

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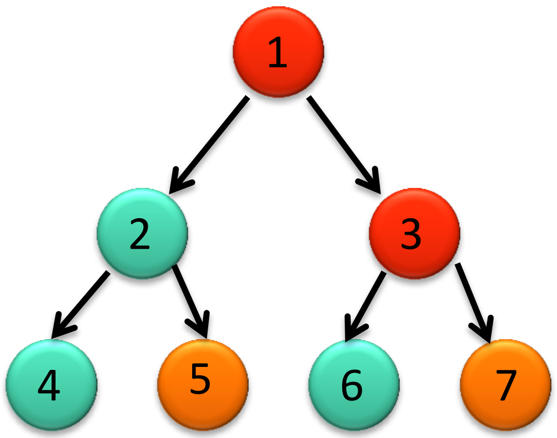

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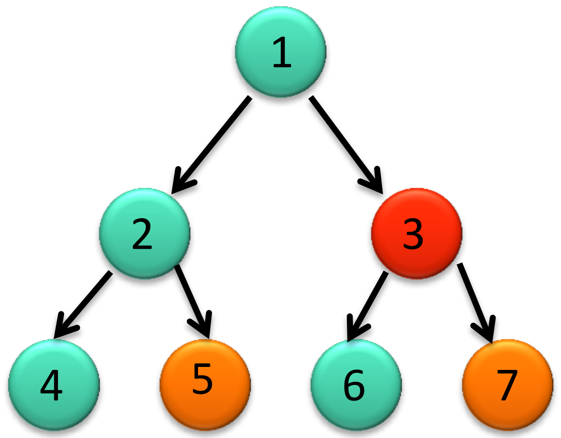

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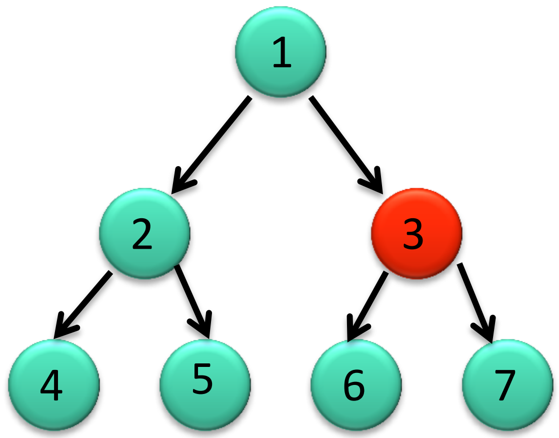

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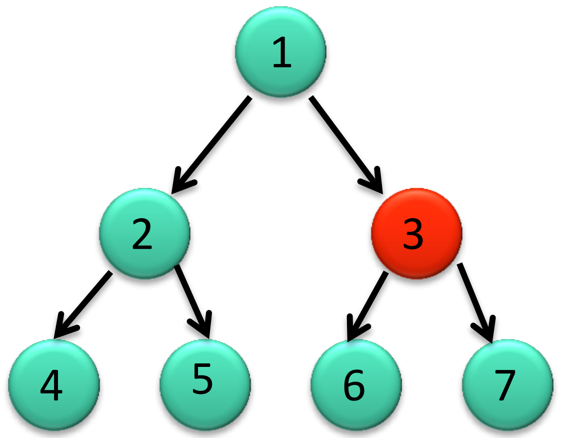

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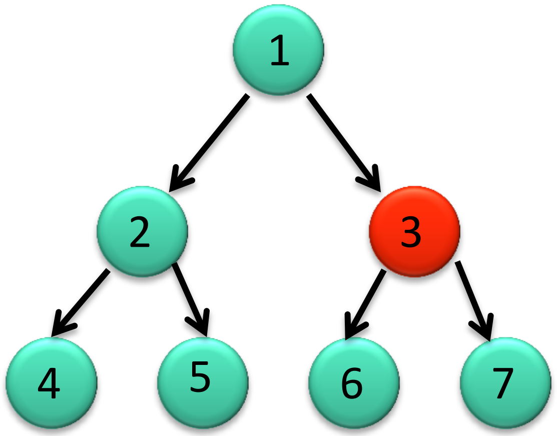

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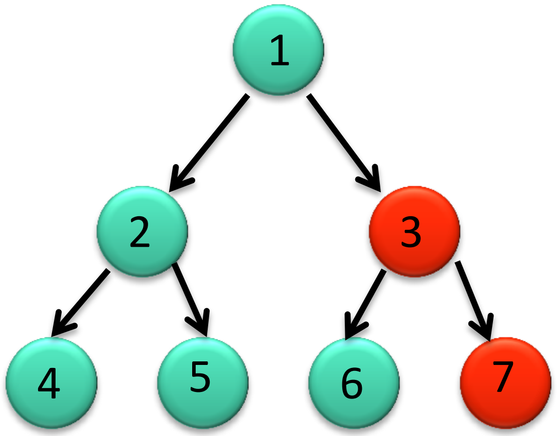

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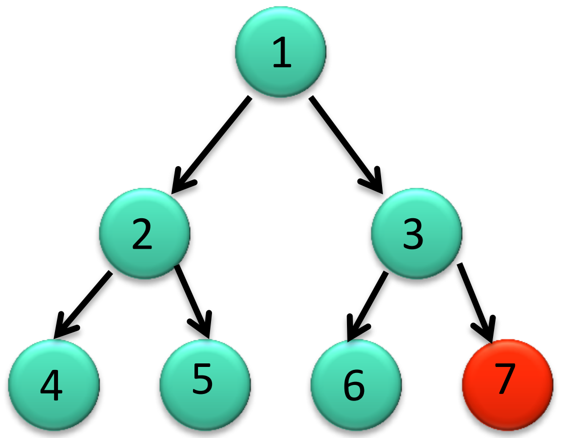

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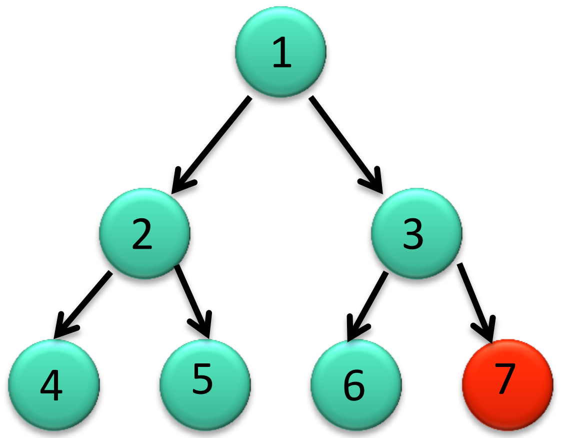

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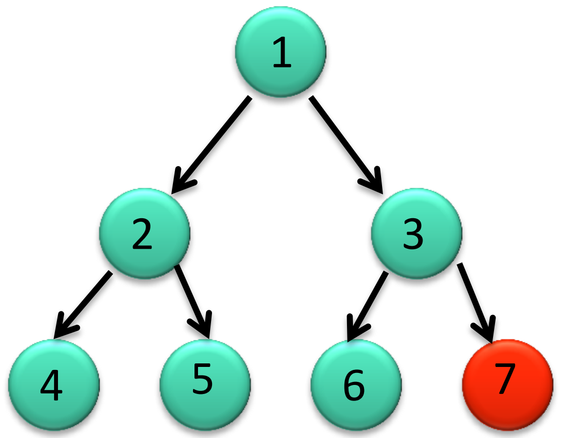

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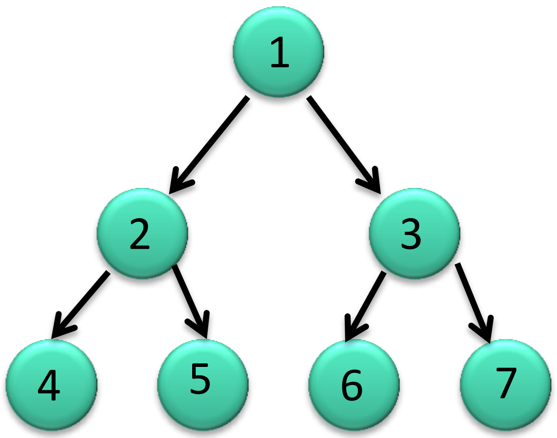

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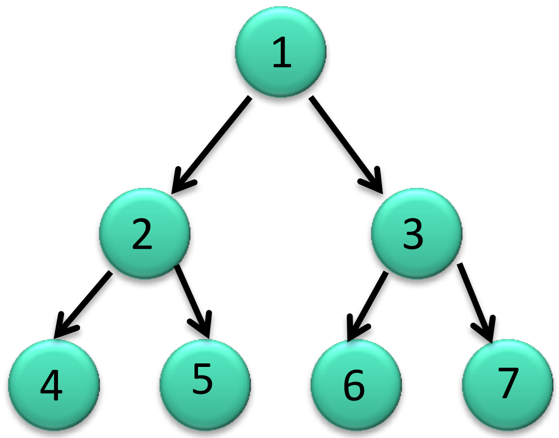

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    value = someComputation;
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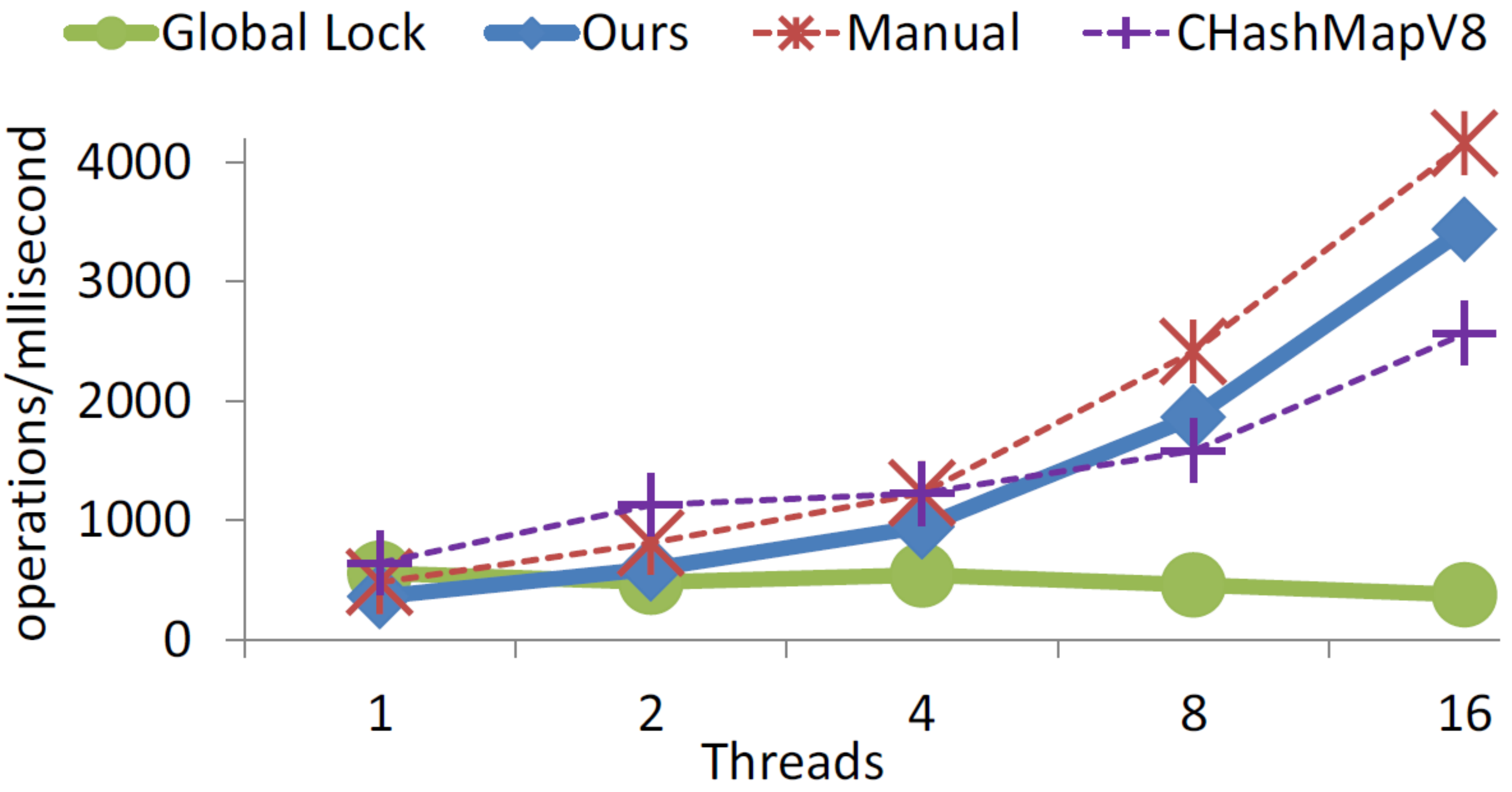

Global Lock
Ours
Manual
CHashMapV8
operations/mllisecond
4000
3000
2000
1000
0
1
2
4
8
16
Threads

Evaluation

- ComputeIfAbsent-pattern:

```
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- At most 25% slower than the hand-crafted fine-grained locking

Questions?