Concurrency Control of Ordered Linked List

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讨论一个有序链表的并发控制相关技术

多核处理编程的艺术-第9章

模型：有序链表

- 假定有序链表不允许重复元素
- 方法
  - add(x) 增加一个元素
  - remove(x) 删除一个元素
  - contains(x) 查找一个元素
- 每个节点包括
  - Key
  - 一个指向后面节点的指针 next

基本操作

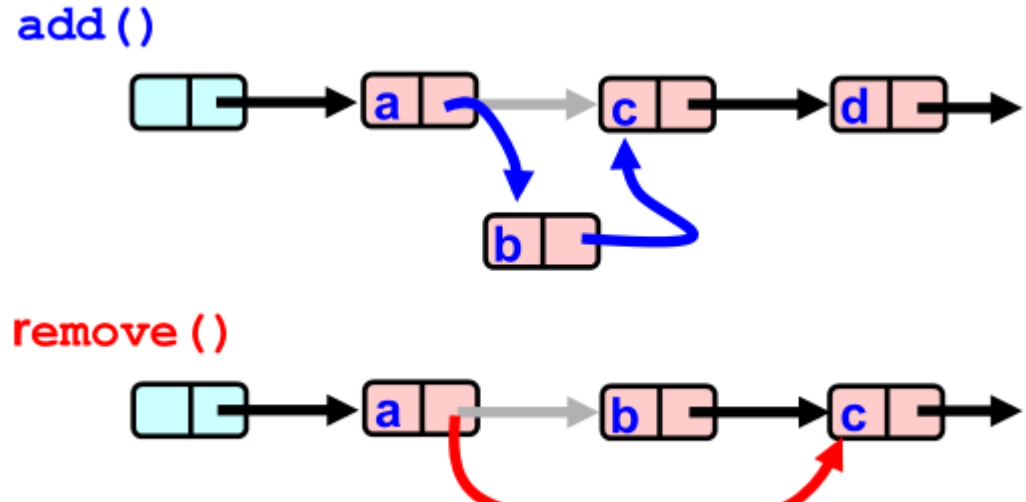
Add()

node.next = curr;

pred.next = node

Remove()

pred.next = curr.next

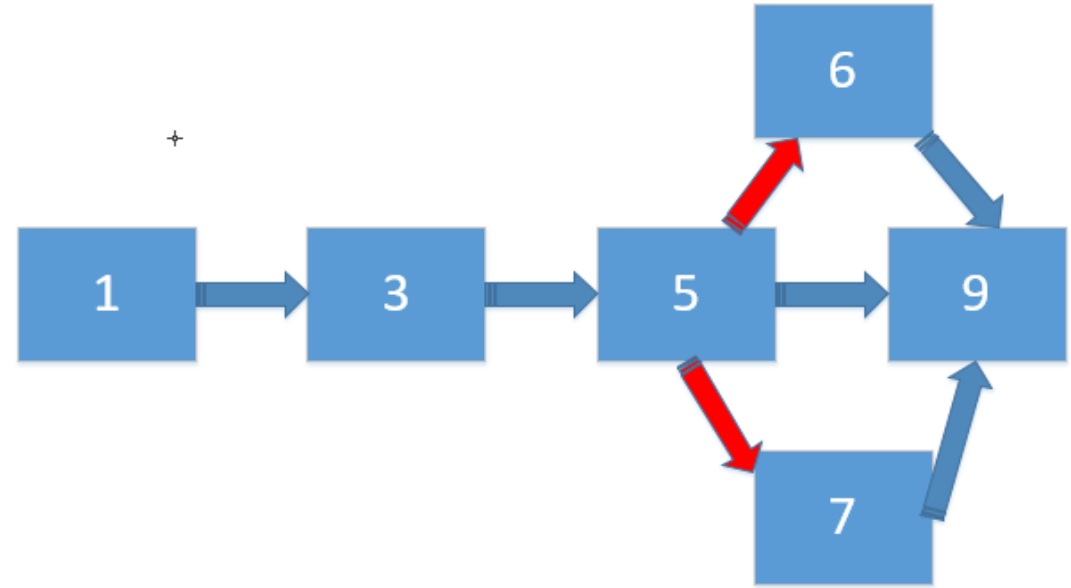


并发控制上的异常

- 丢失更新
- 假删除
- 插入节点被删除

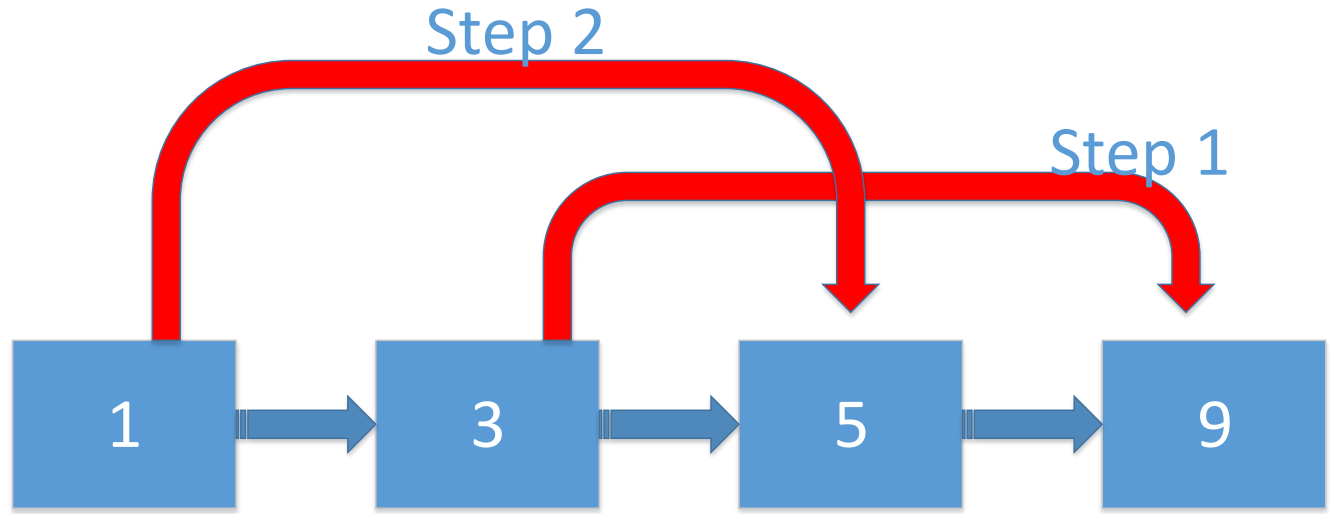
并发控制的异常

- 丢失更新
- add和add
  - 同时插入6和7



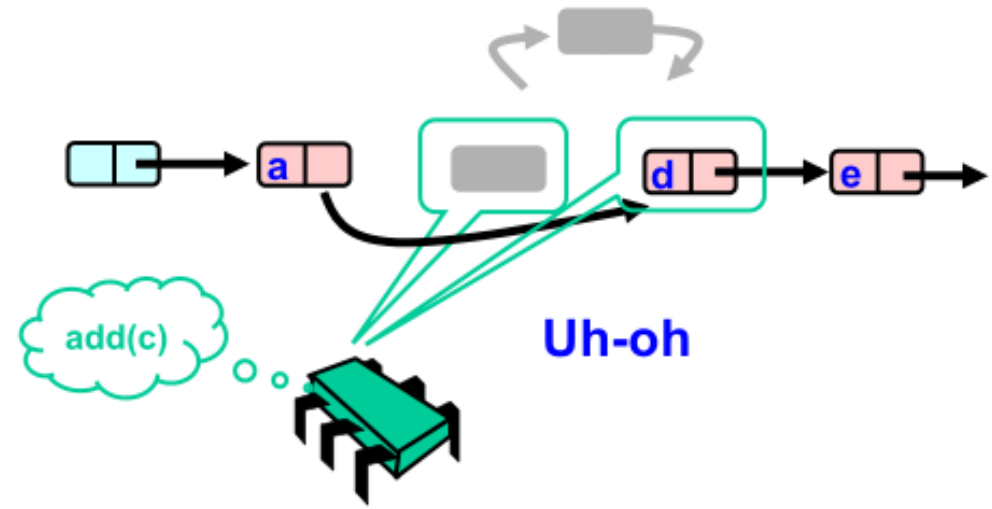
并发控制的异常

- 假删除问题
  - remove和remove
  - 同时删除3, 5 ， 5未真正删除



并发控制上的异常

- 插入节点被删除
  - add和remove
  - 插入的后节点被删除
  - 插入的前节点被删除
    - 删除b, 插入c



并发控制的方法

- 并发控制
  - 防止异常的发生
- 方法
  - 粗粒度锁
  - 细粒度锁（hand over hand locking或lock coupling）
  - 乐观锁
  - 懒惰锁
  - ~~无锁编程(原子操作)~~

粗粒度锁

- 对add(), remove(), contains()三个操作
  - 访问链表时加锁，操作完成后释放锁
  - 最安全
  - 效率最差

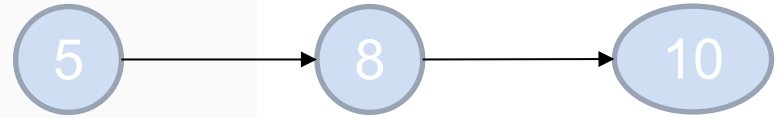
Lock Coupling

Hand over hand Locking

- 链表向前推进时先获取锁时，先获取curr锁，然后再释放prev锁
- 数据操作时，同时锁住前驱和后继

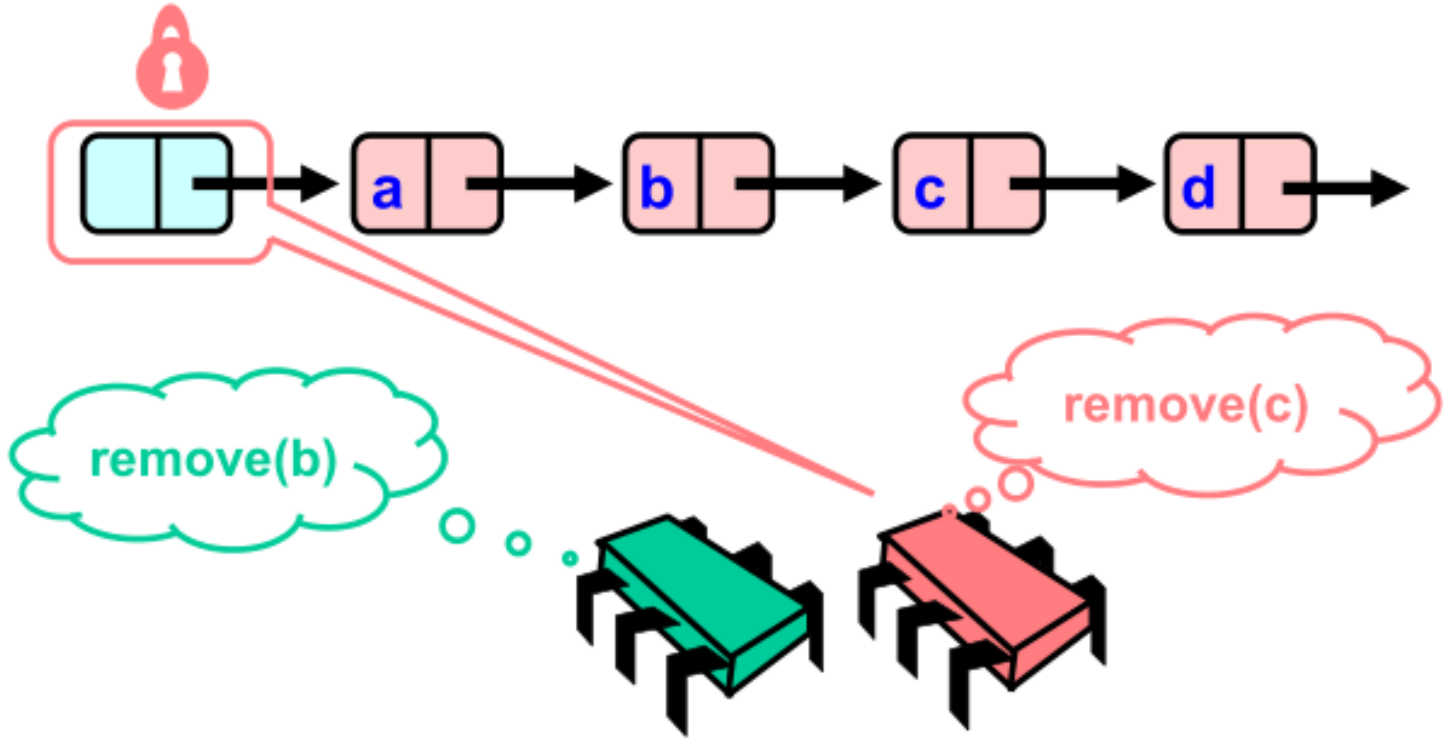
Lock Coupling的一些代码

```
head.lock();
pred = head;
try{
        curr = pred.next;
        curr.lock();
        try{
                while(curr.key < key){
                        pred.unlock();
                        pred = curr;
                        curr = curr.next;
                        curr.lock();
                }
                if(curr.key == key){
                        return false;
                }
                NodeWithLock<T> node = new NodeWithLock<T>(item);
                node.next = curr;
                pred.next = node;
                return true;
        }finally{
                curr.unlock();
        }
}finally{
        pred.unlock();
}
```

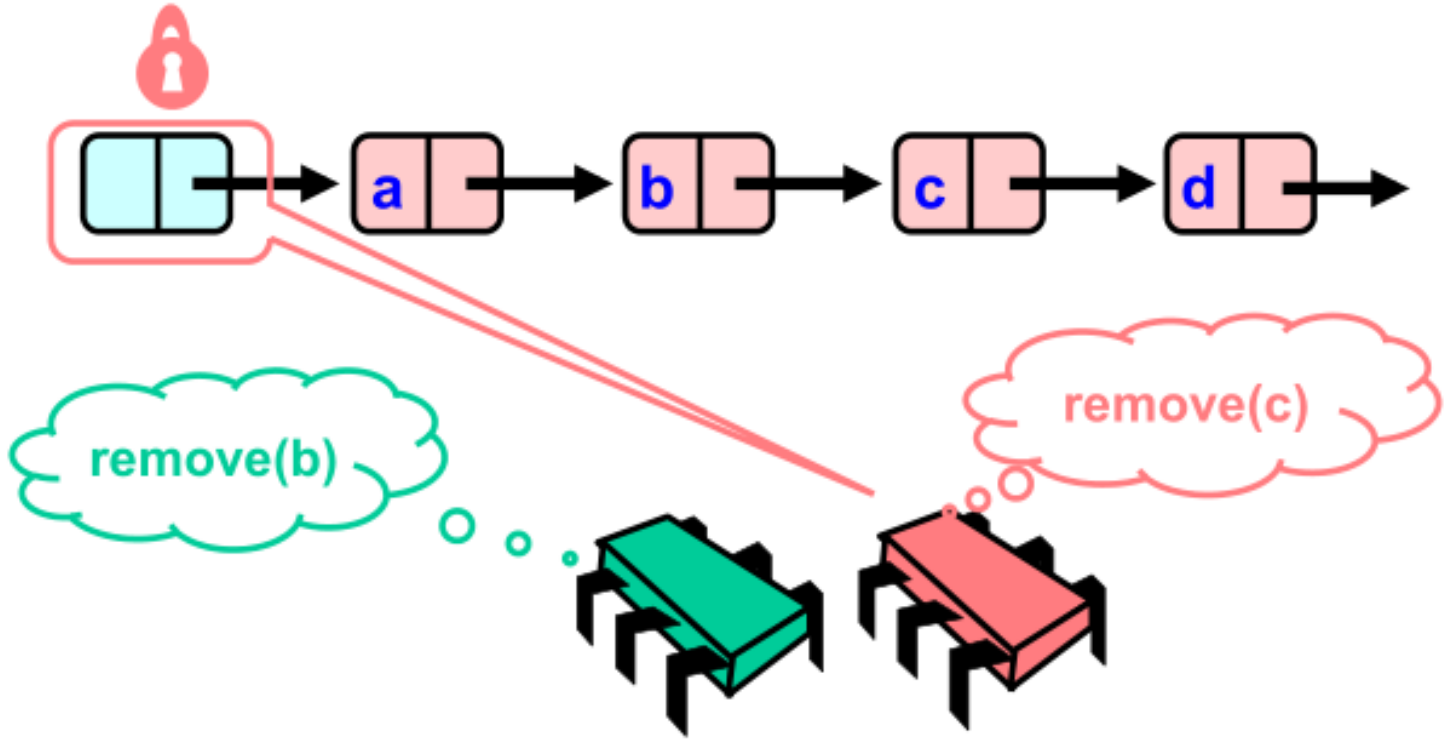


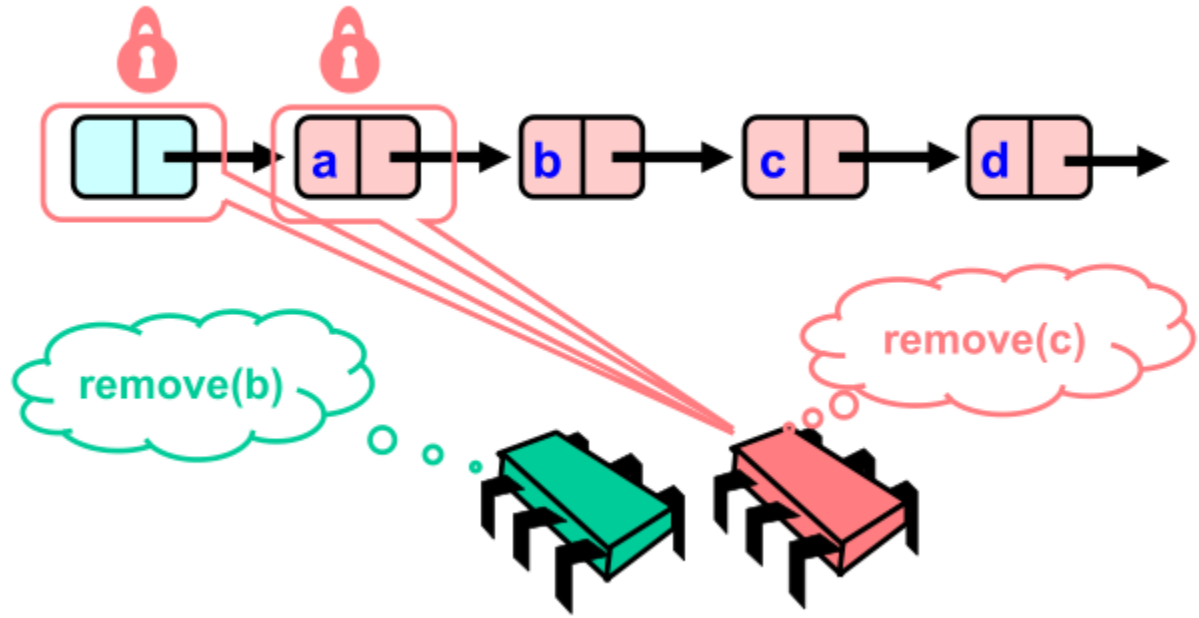
插入操作

Lock Coupling举例

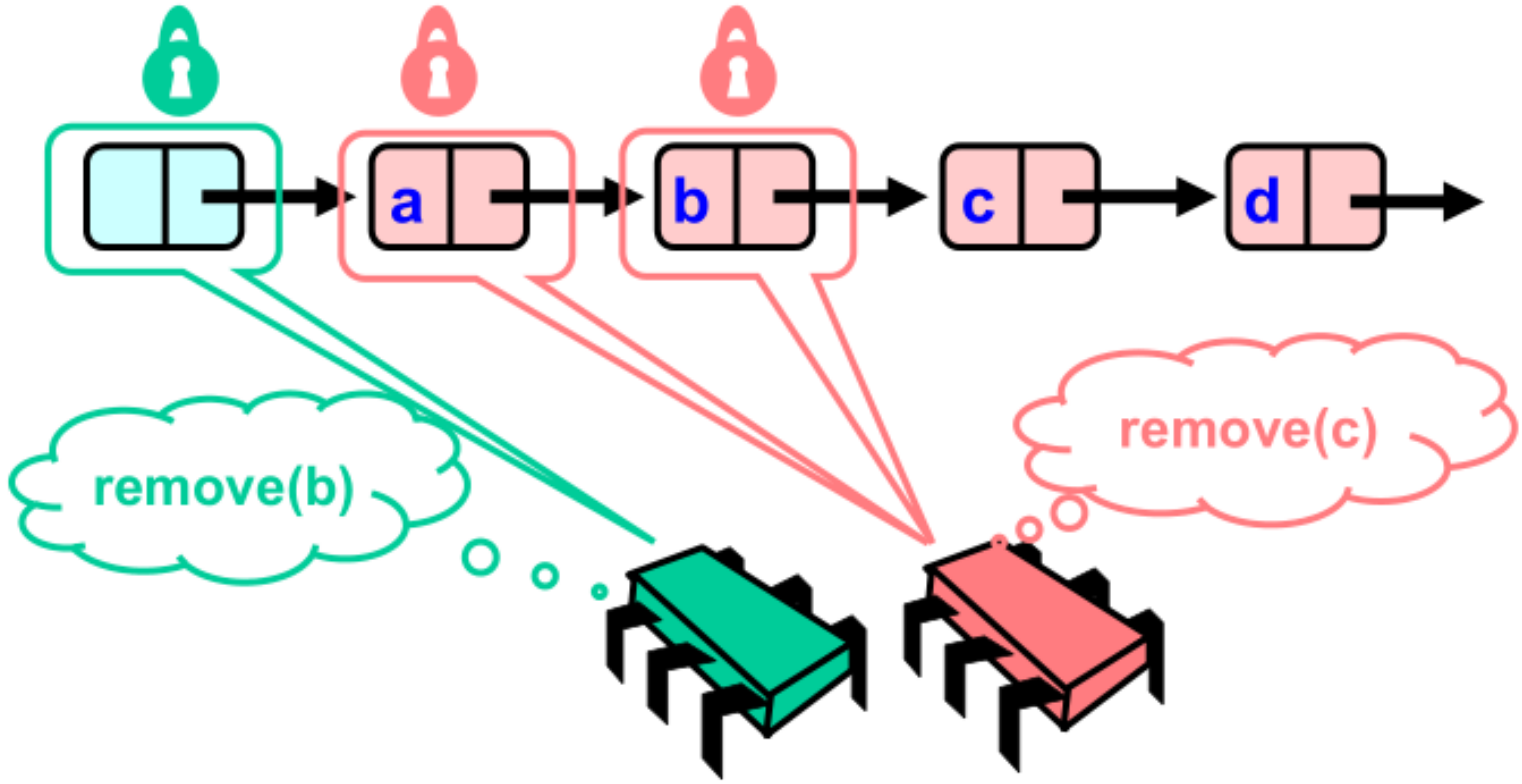


Lock Coupling举例

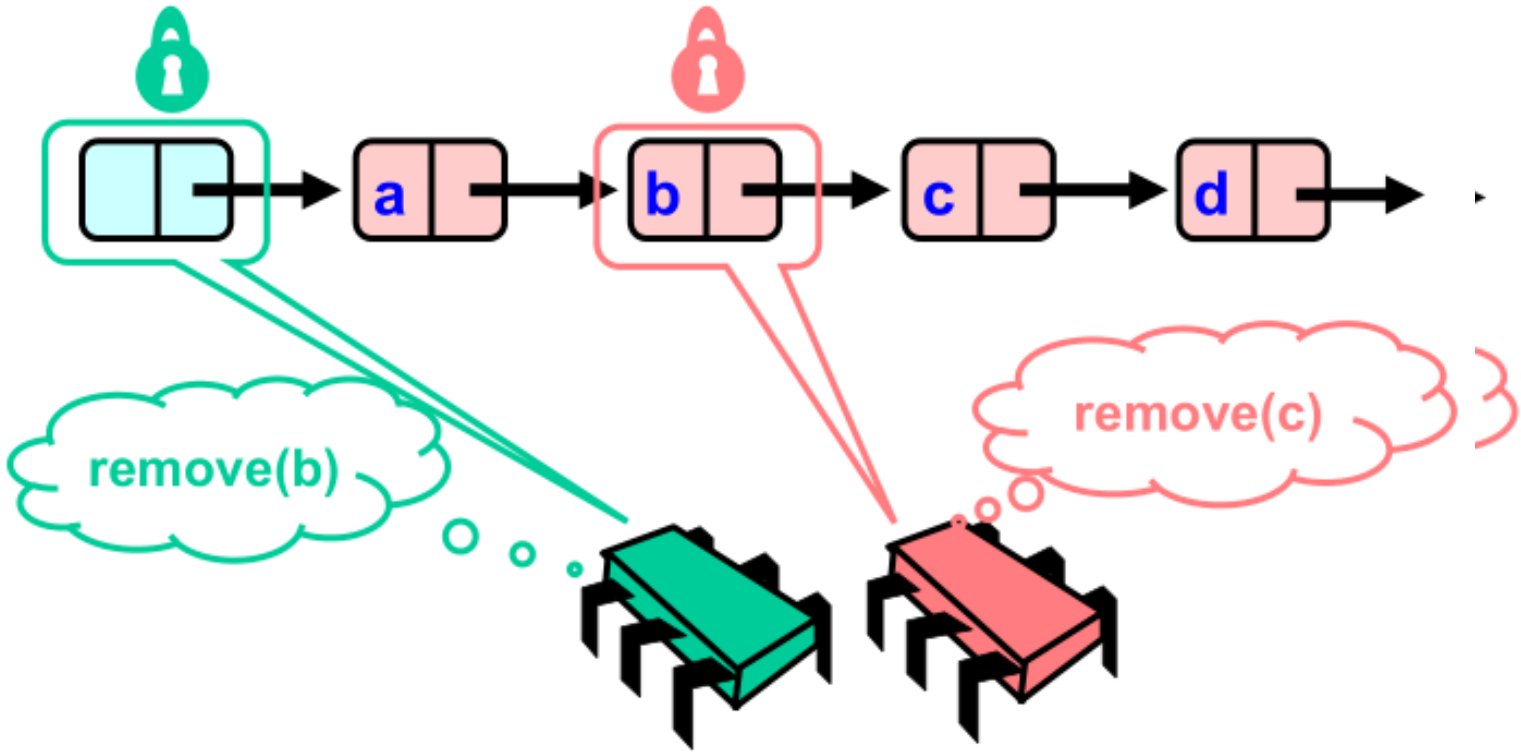


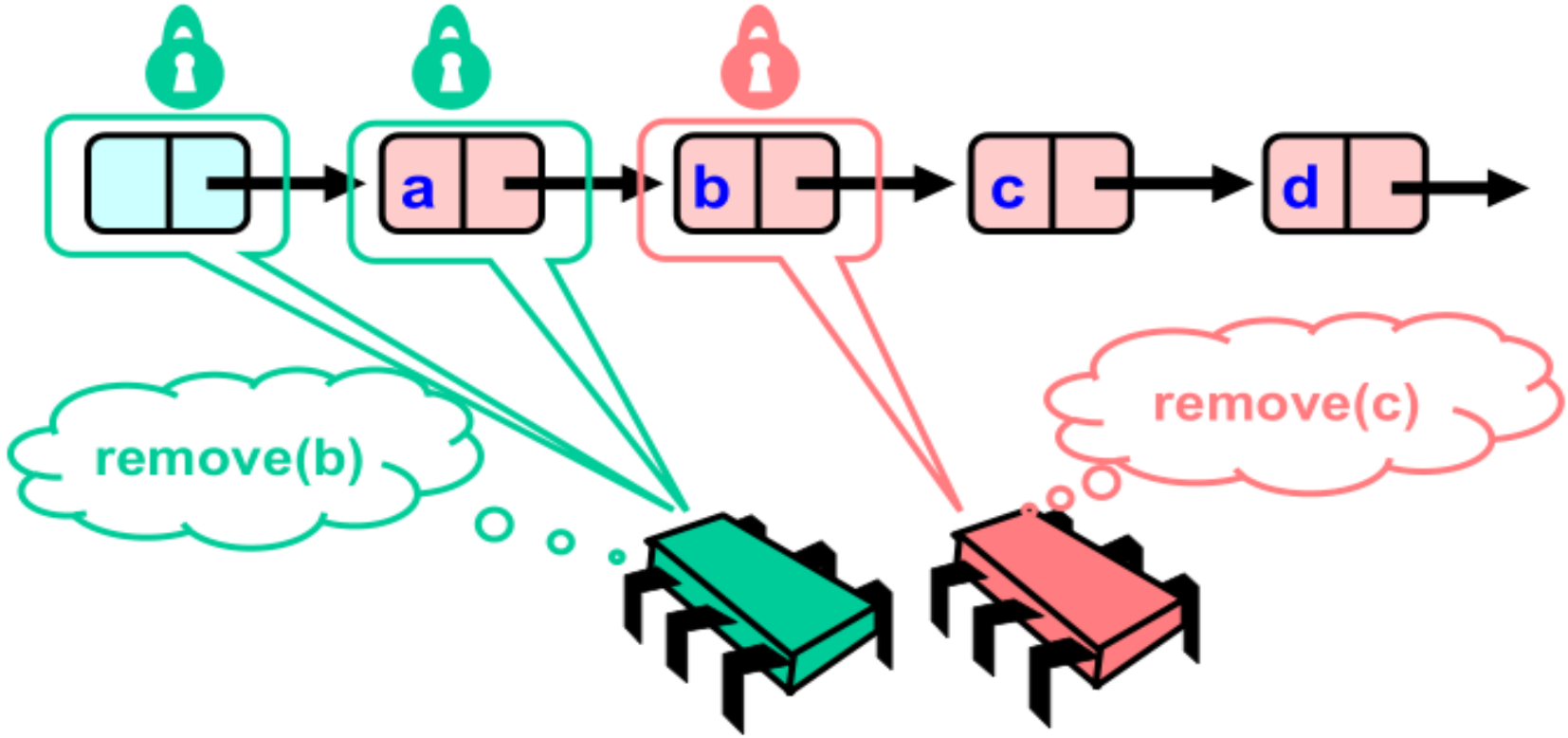

a
b
c
d
remove(b)
remove(c)

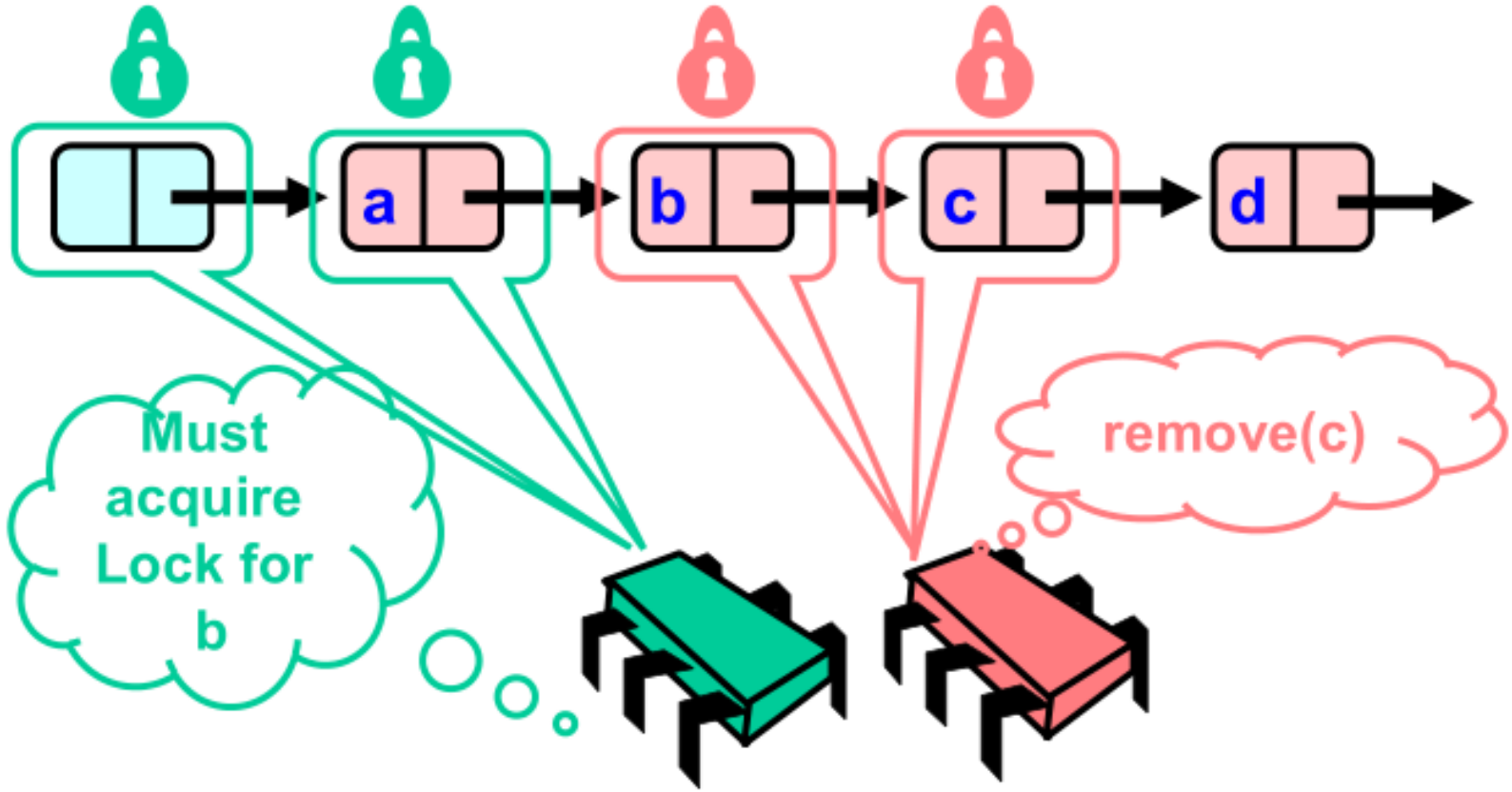
Lock Coupling举例

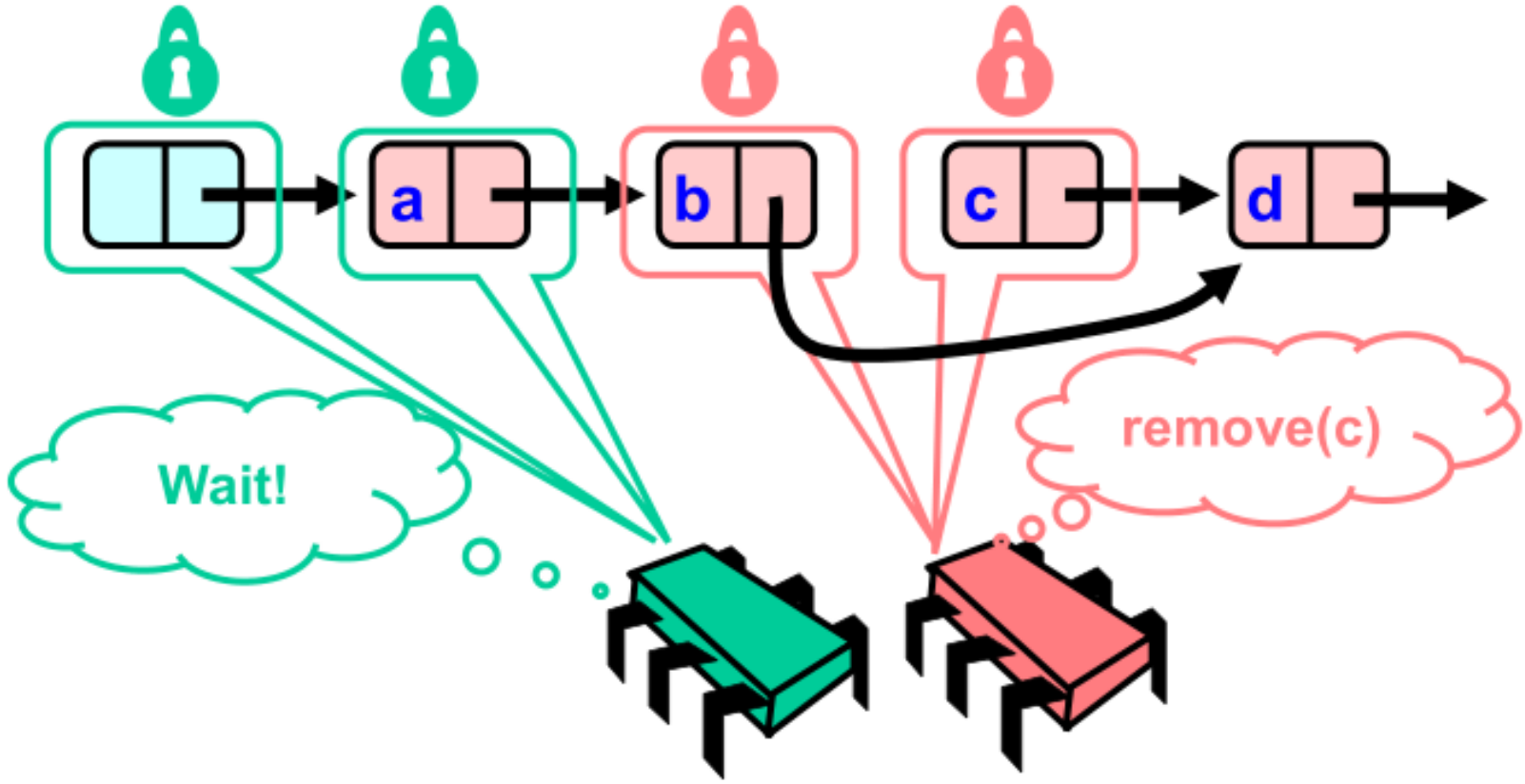


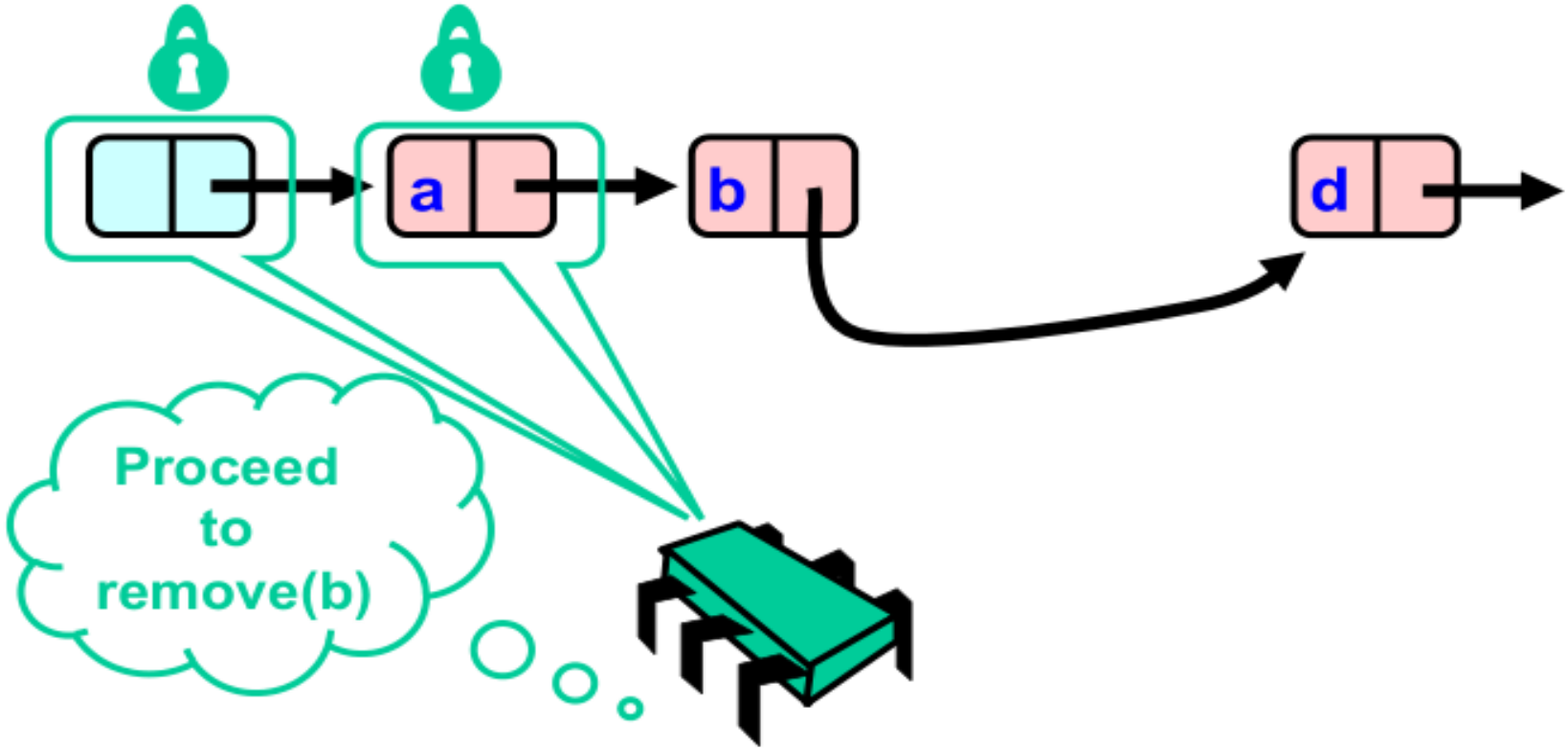
Lock Coupling举例

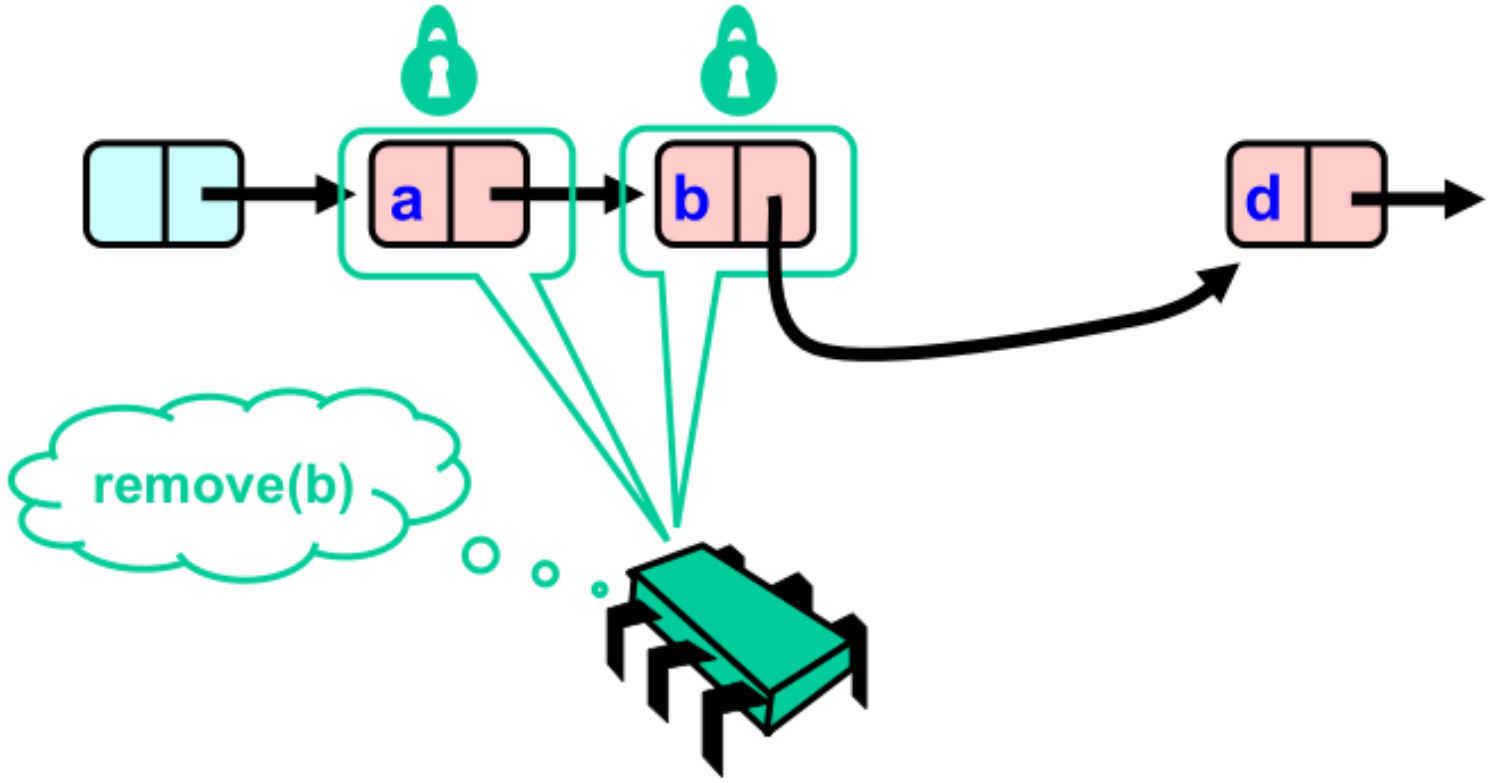



a
b
c
d
remove(b)
remove(c)

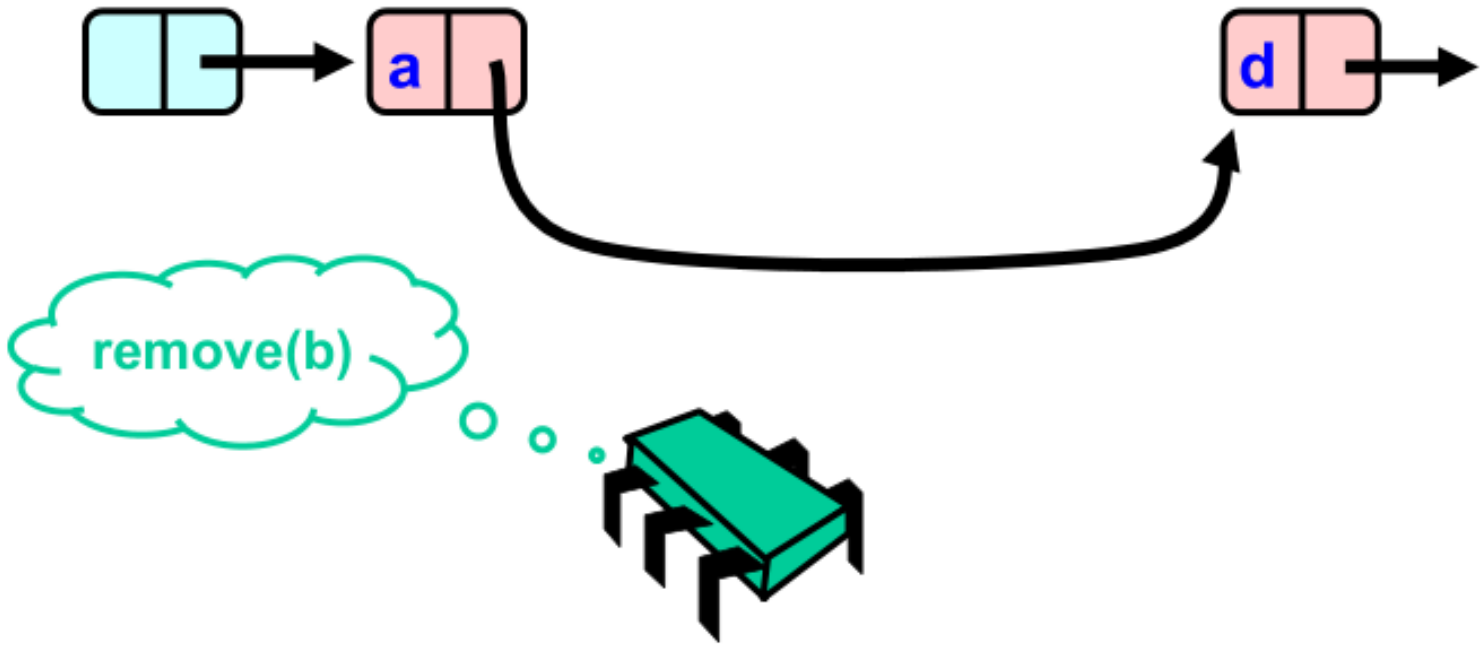

a
b
c
d
Must acquire Lock for b
remove(c)


a
b
c
d
Wait!
remove(c)


a
b
d
Proceed
to
remove(b)


a
b
d
remove(b)

避免了假删除问题



Lock Coupling

- Remove()
  - 锁住删除节点和其前驱节点，然后再删除
- Add()
  - 锁住插入节点的前驱和后续节点，然后插入

如果不做Lock Coupling

- Remove()
  - 如果不锁删除节点?
  - 如果不锁前驱节点？
    - 无法避免假删除问题

如果不做Lock Coupling

- Add()
  - 如果不锁前驱节点?
    - 仍然无法避免丢失更新
  - 如果不锁后继节点？
    - 请大家思考

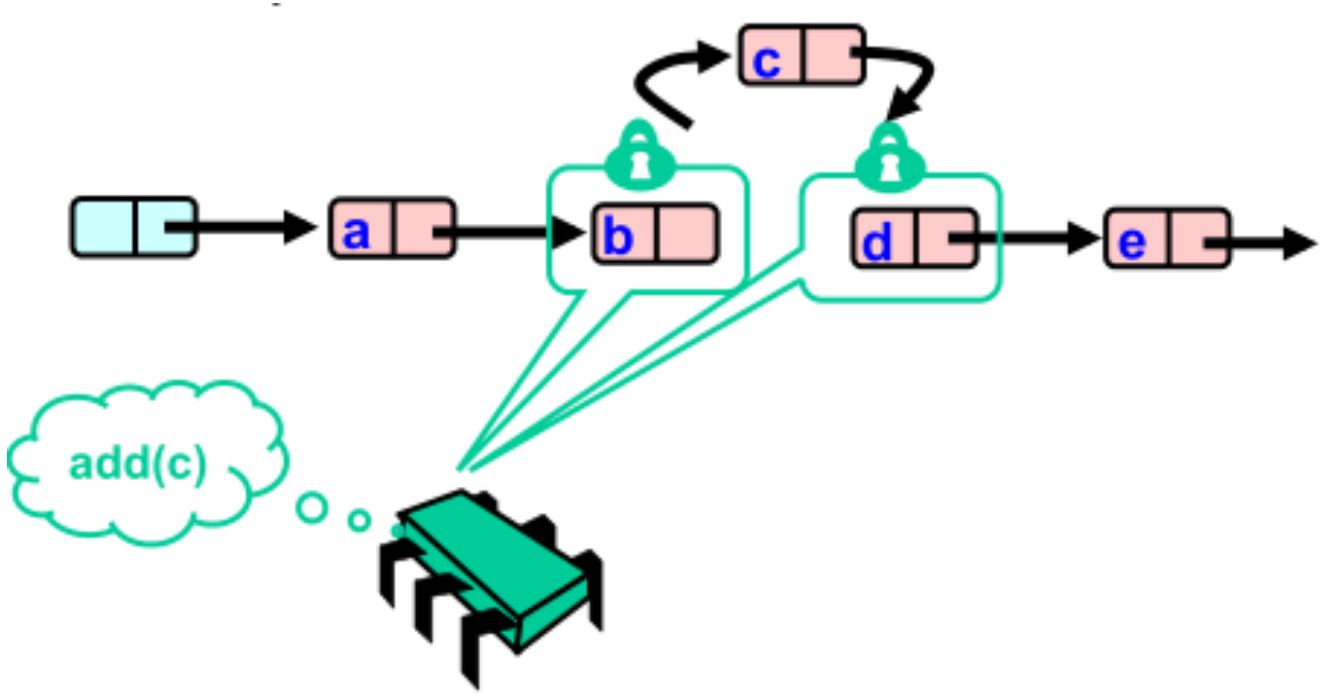
乐观锁

乐观锁

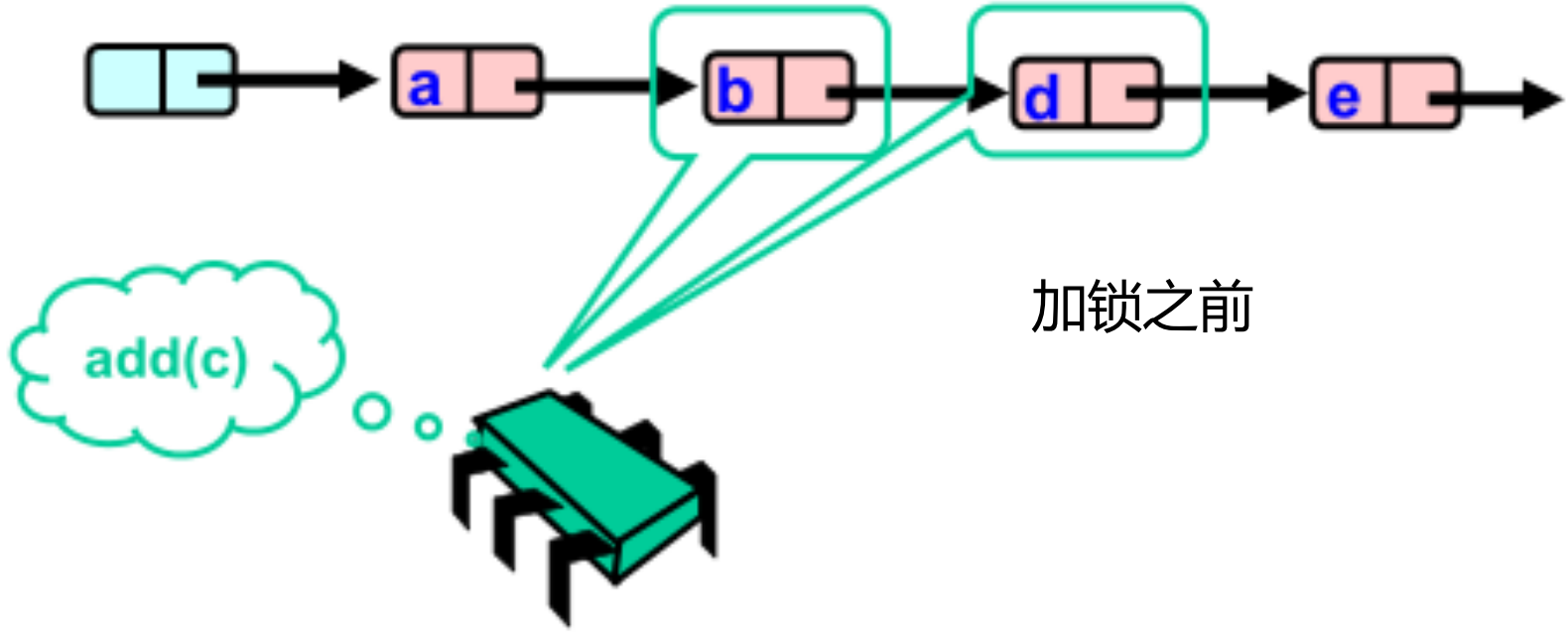
- Lock Coupling需要不停的去获得和释放锁
- 只在需要加锁的时候再加锁
  1. 只有在寻找到要加锁位置的时候才加锁，之前不加锁
  2. 需要加锁时，先加锁，再进行验证是否现场已经被修改
  3. 如果验证失败就需要从头开始重试

无锁遍历

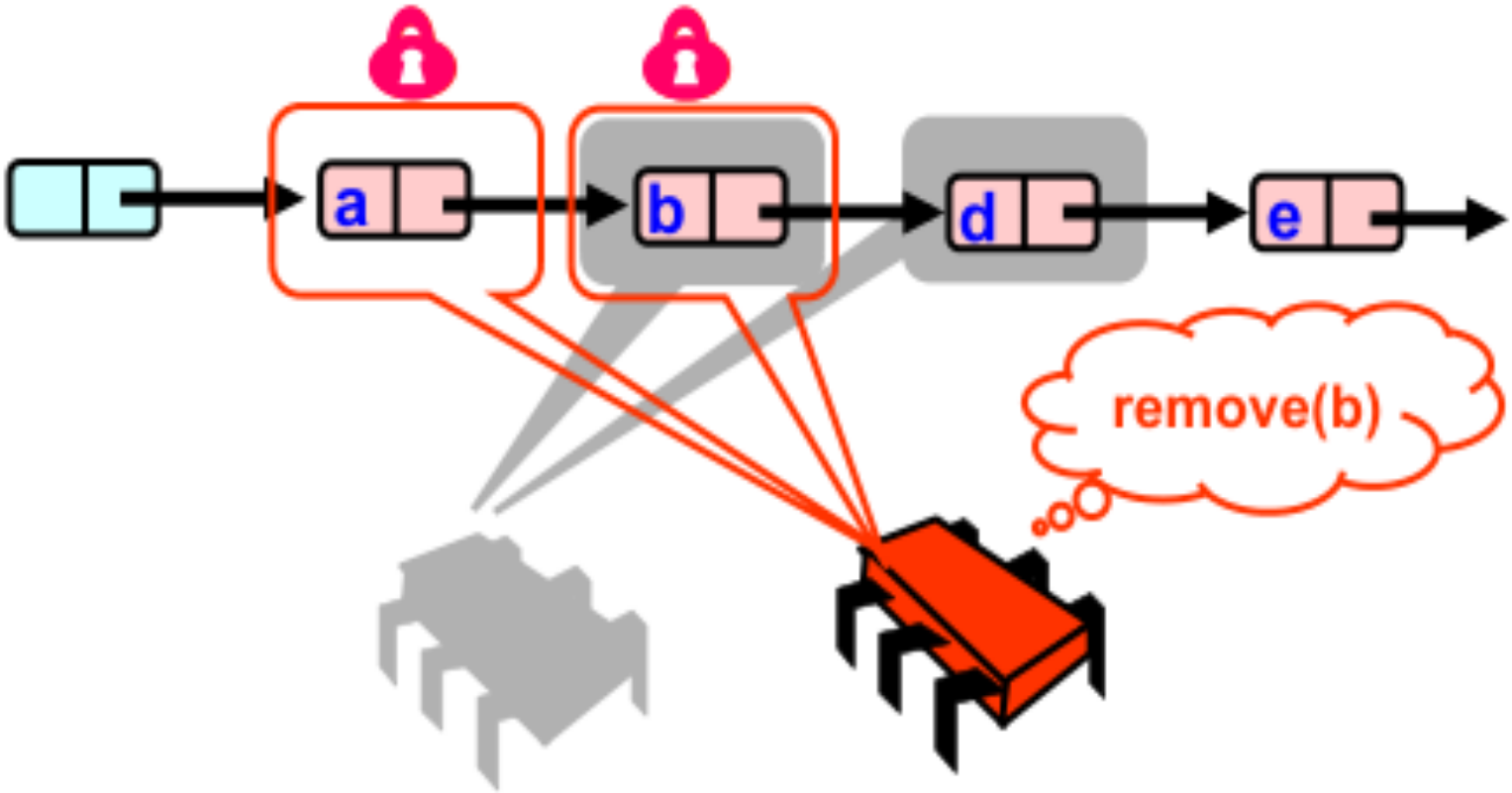
- what could go wrong?



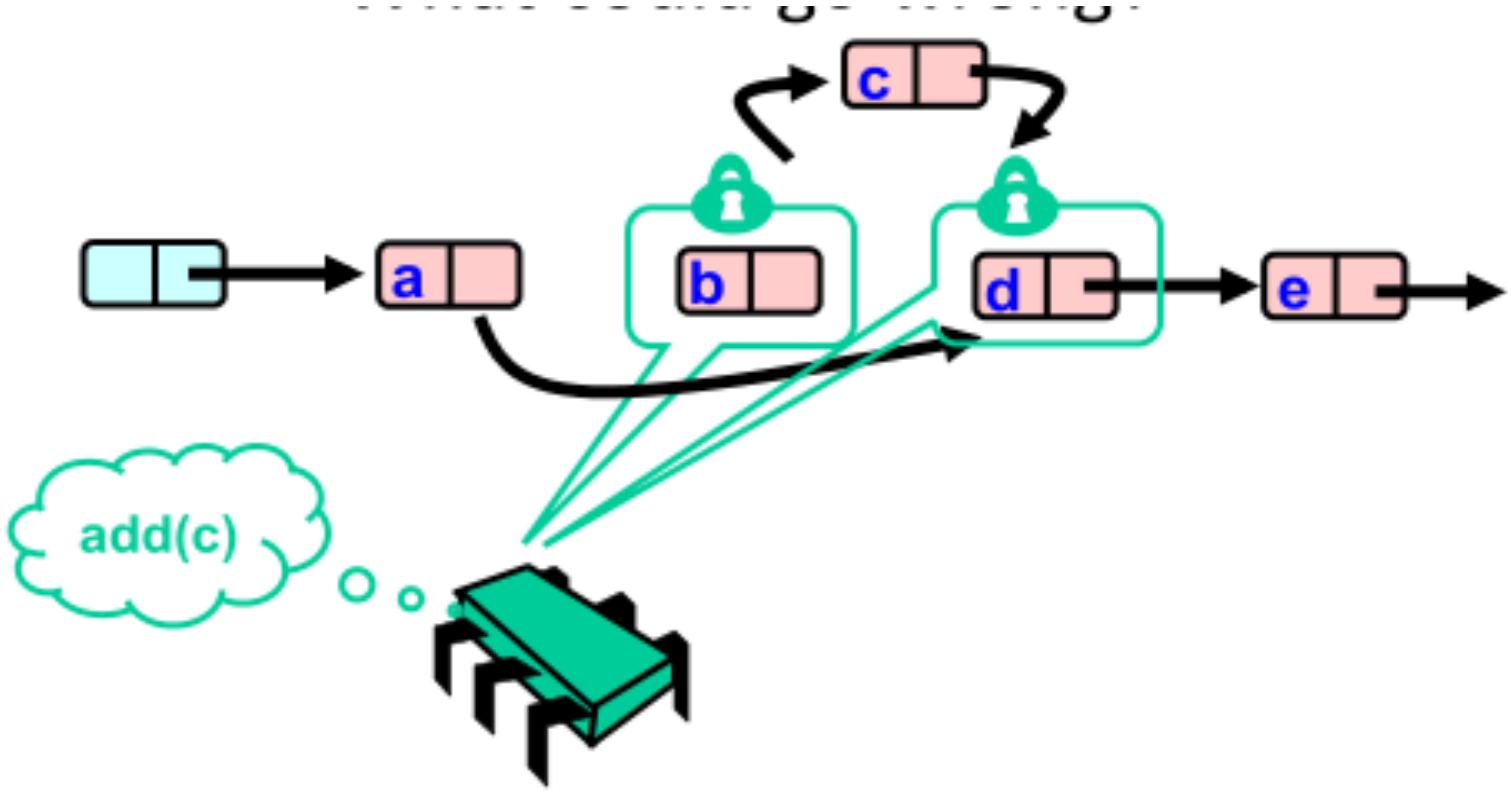
无锁遍历的异常（一）



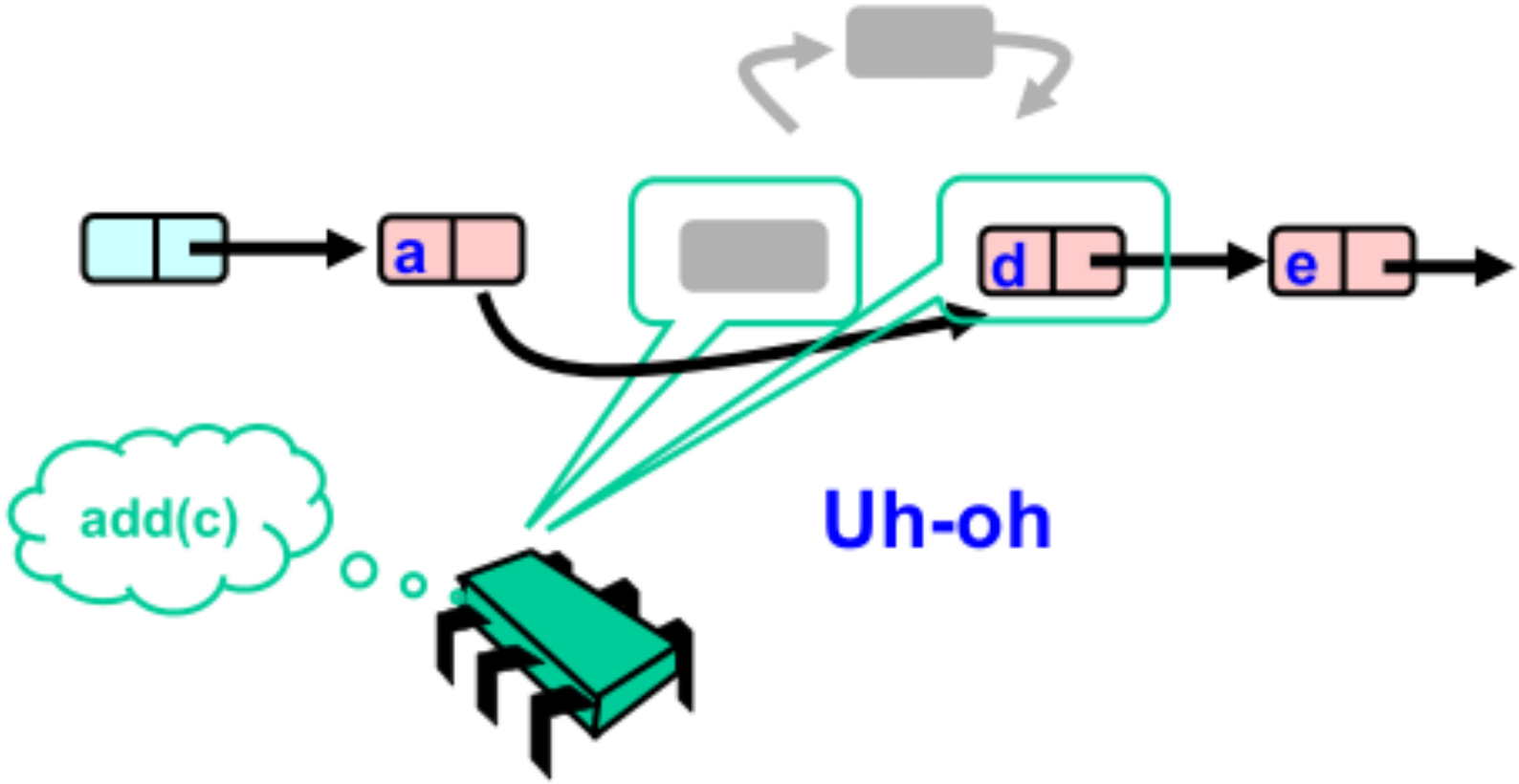
无锁遍历的异常（一）



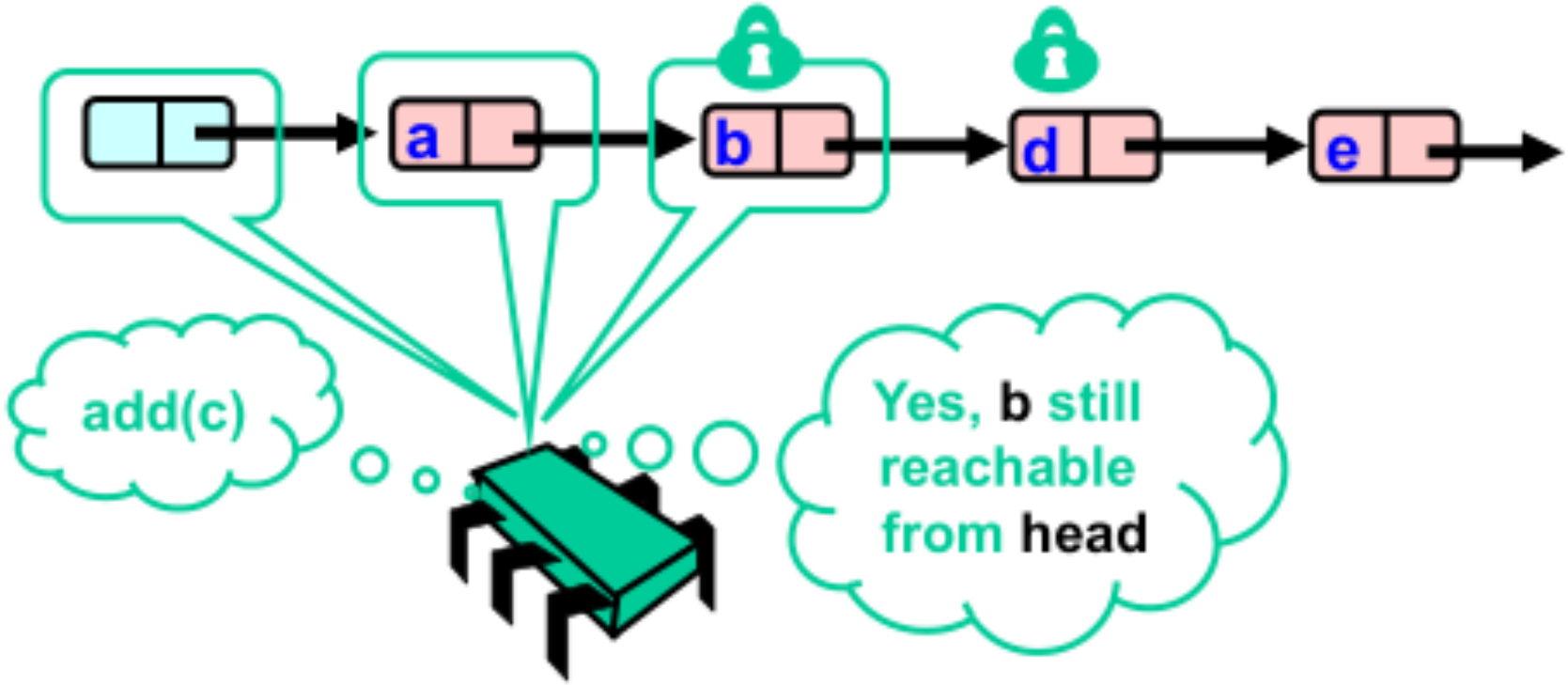
无锁遍历的异常（一）



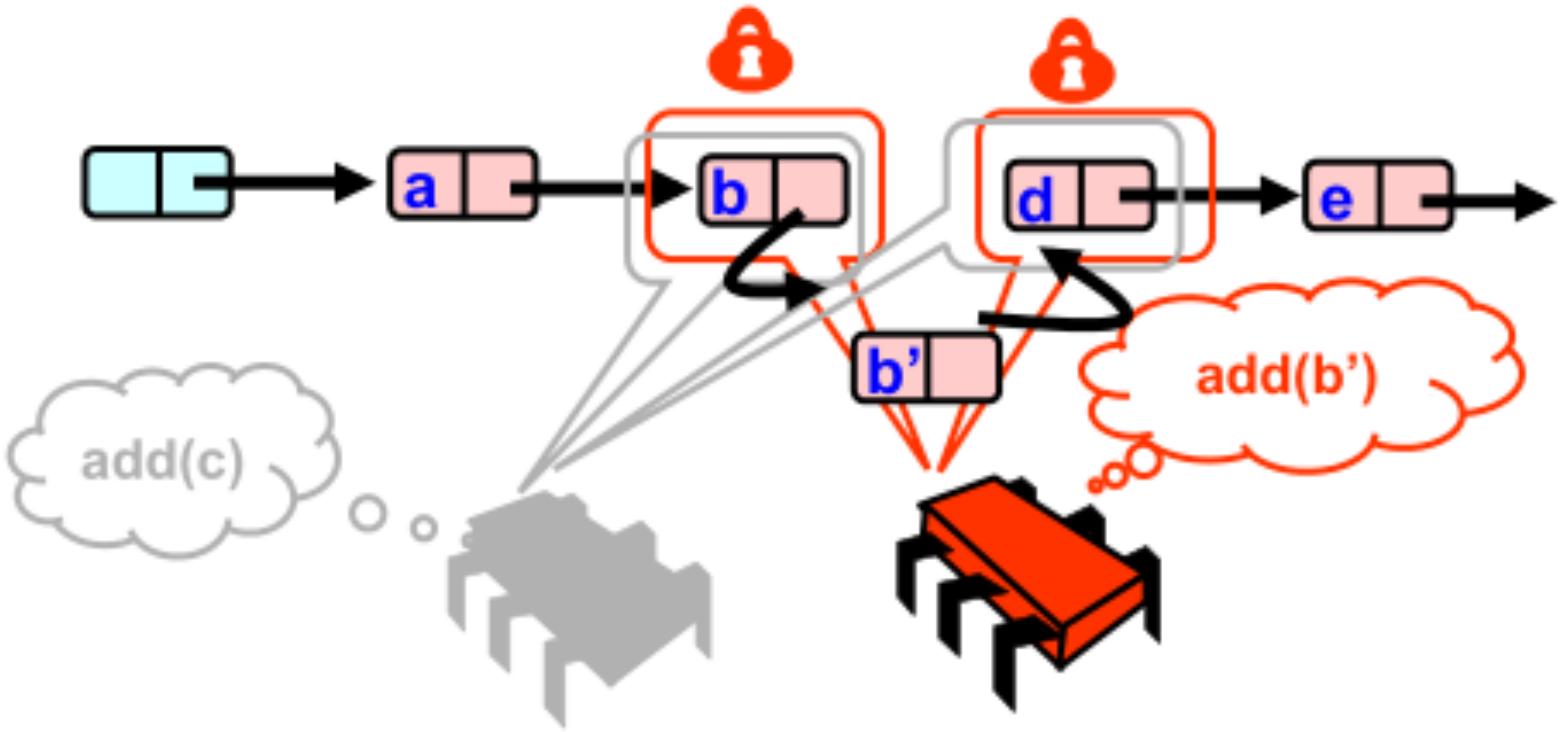
无锁遍历的异常（一）



验证b是否仍然可达

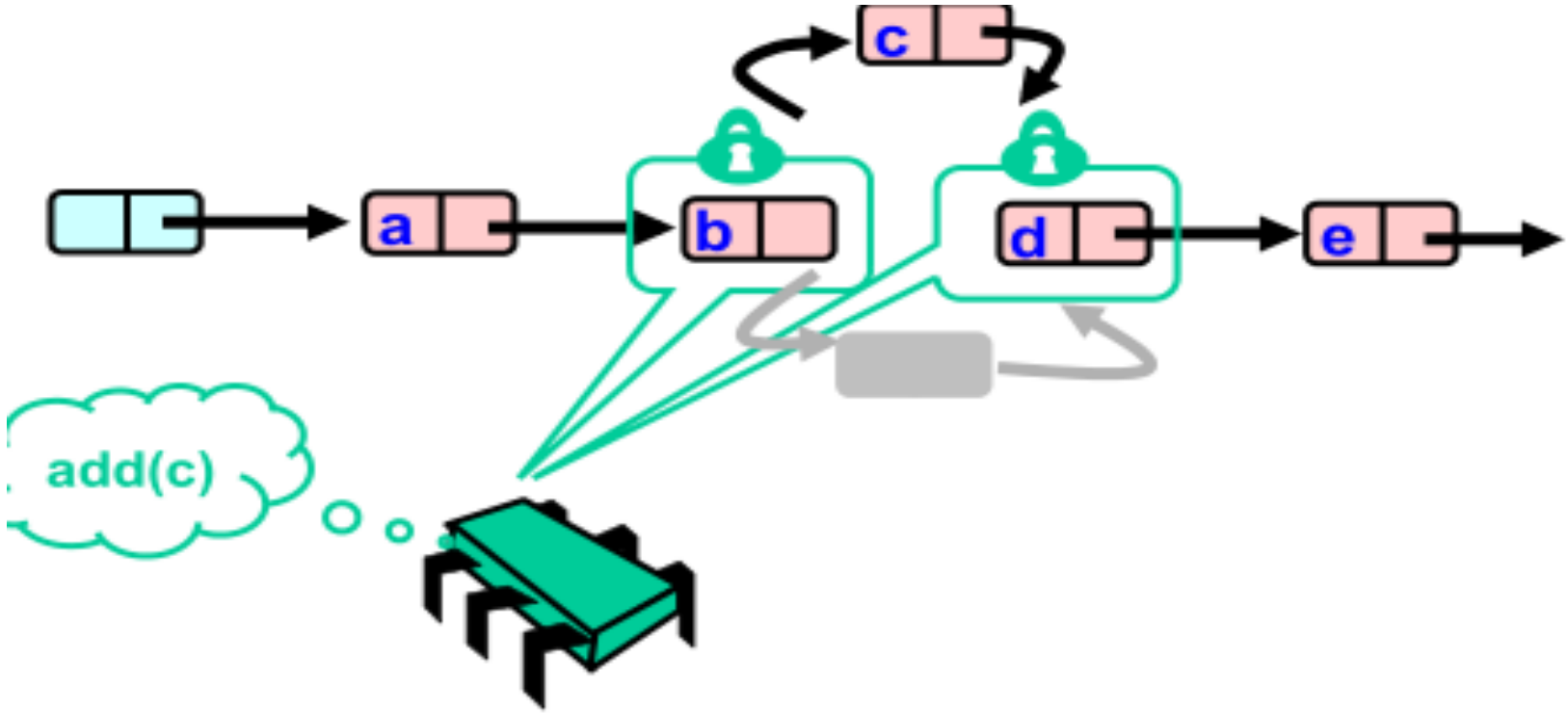


无锁遍历异常(二)

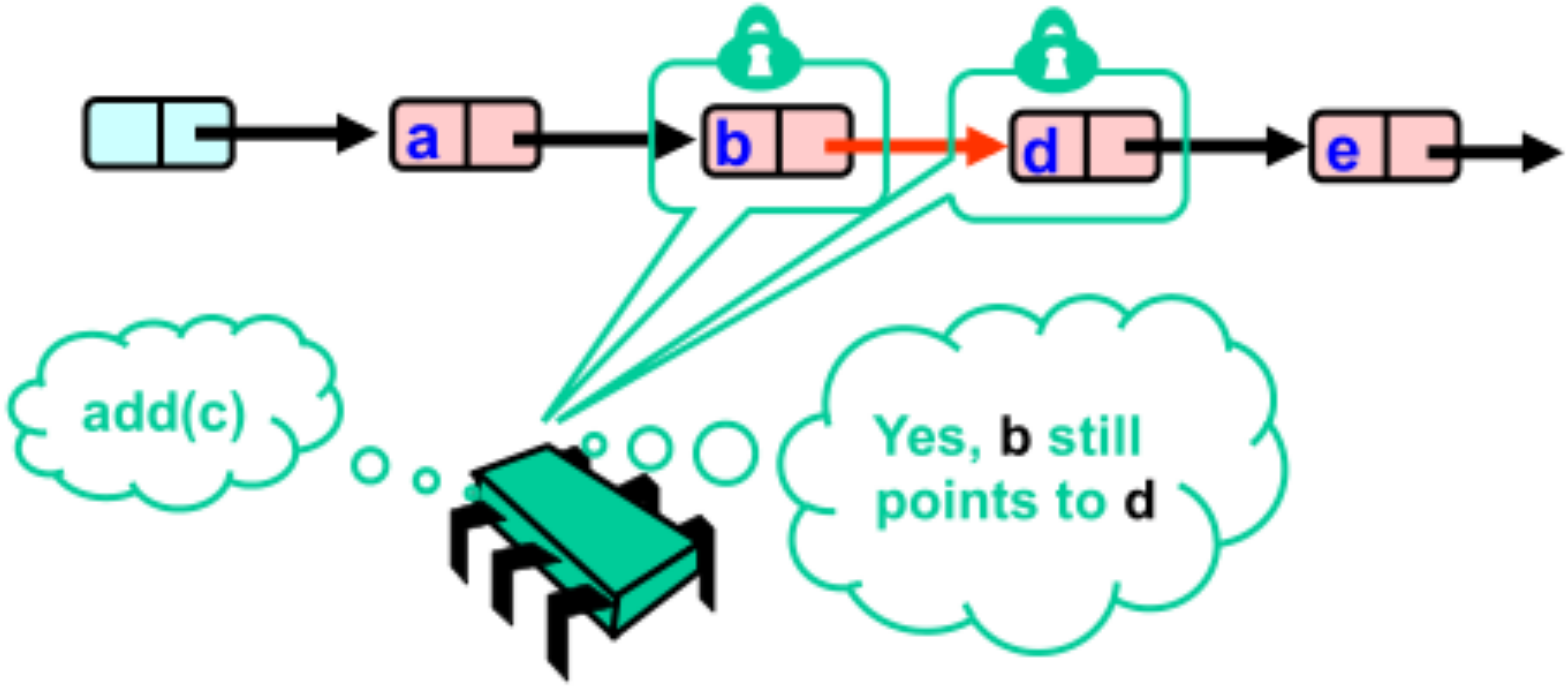


无锁遍历异常(二)

- 丢失更新



验证b和d之间仍连接



验证代码

```
private boolean
 validate(Node pred,
          Node curry) {
 Node node = head;
 while (node.key <= pred.key) {
  if (node == pred)
   return pred.next == curr;
  node = node.next;
 }
 return false;
}
```

Add代码，无锁遍历

```
while(true){
        pred = head;
        curr = pred.next;

        while(curr.key < key){
                pred = curr;
                curr = curr.next;
        }
        pred.lock();
        curr.lock();
        try{
                if(validate(pred, curr)){
                        if(curr.key == key){
                                return false;
                        }
                        NodeWithLock<T> node = new NodeWithLock<T>(item);
                        node.next = curr;
                        pred.next = node;
                        return true;
                }
        }finally{
                pred.unlock();
                curr.unlock();
        }
}
```

Contains代码

```
while(true){
        pred = head;
        curr = pred.next;

        while(curr.key < key){
                pred = curr;
                curr = curr.next;
        }
        pred.lock();
        curr.lock();
        try{
                if(validate(pred, curr)){
                        return curr.key == key;
                }
        }finally{
                pred.unlock();
                curr.unlock();
        }
}
```

讨论contains是否需要验证？

- contains和remove可能有异常
  - 如果查找元素本身已被删除
    - 可能对一个已不在链表里的节点返回true(和可线性化的点有关，我们认为不允许)
      - A Lazy Concurrent List-Based Set Algorithm
    - 如果查找元素的前驱被删除
      - 链表可能断裂，需要验证

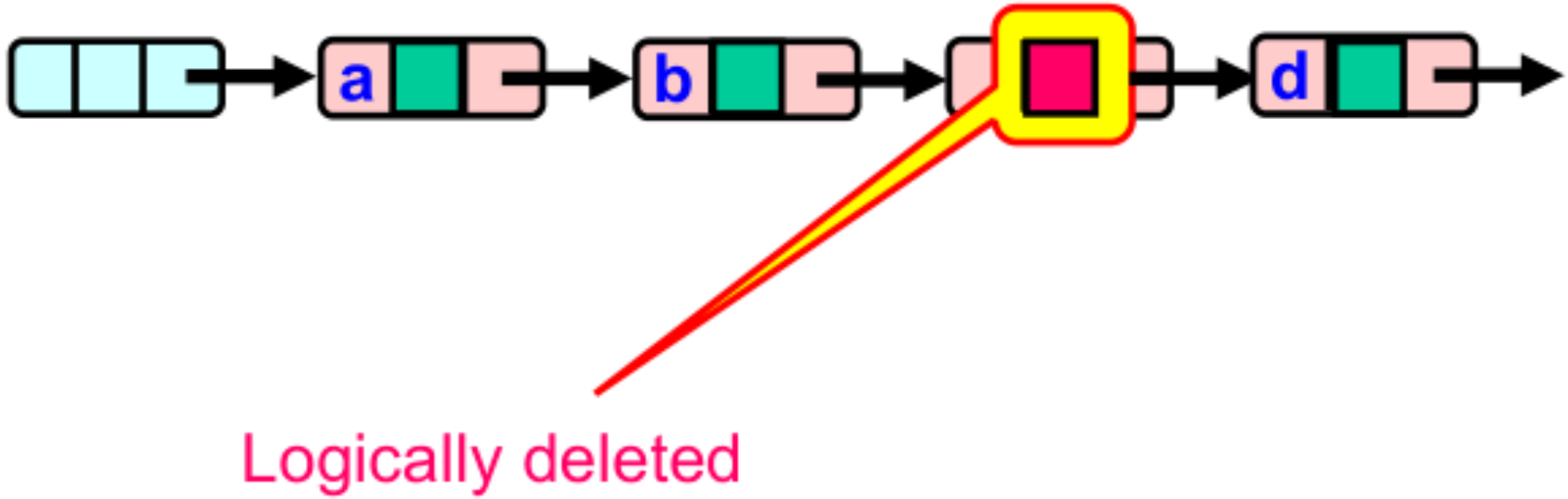
Lazy List

A Lazy Concurrent List-Based Set Algorithm

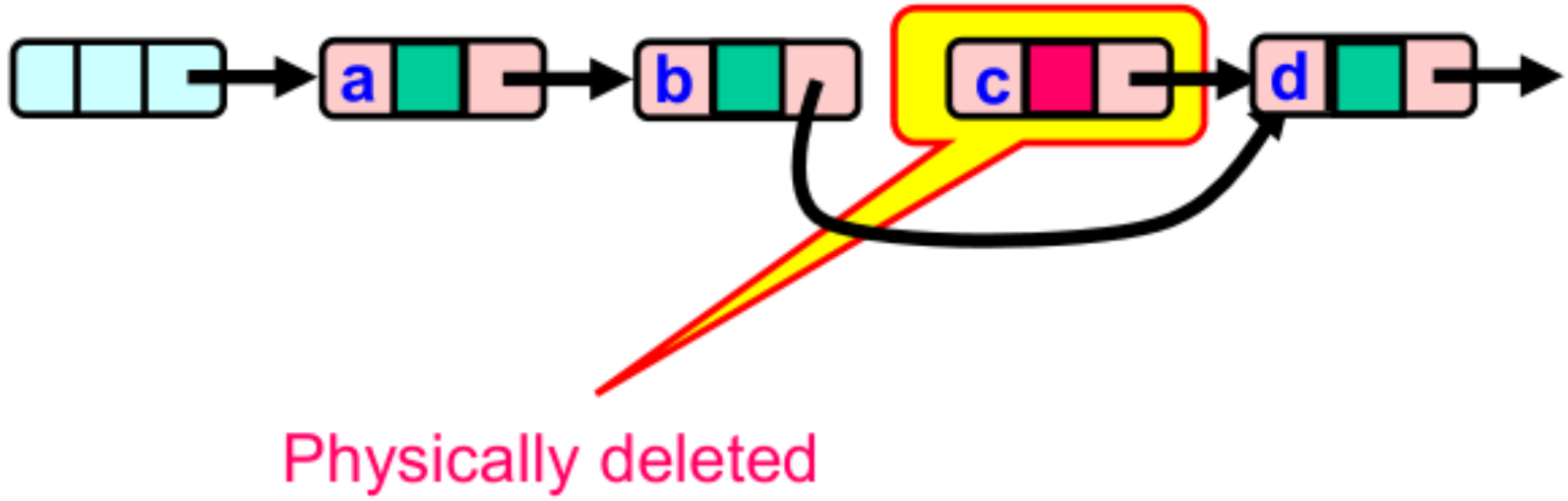
Lazy List

- 乐观锁
  - 仍然需要加锁
  - 可能需要失败重试
- Lazy List
  - 使用标记删除
  - Contains操作无需锁

标记删除



物理删除



验证

```
1   public boolean remove(T item) {
2     int key = item.hashCode();
3     while (true) {
4      Node pred = head;
5      Node curr = head.next;
6      while (curr.key < key) {
7       pred = curr; curr = curr.next;
8       }
9       pred.lock();
10      try {
11        curr.lock();
12        try {
13          if (validate(pred, curr)) {
14            if (curr.key != key) {
15              return false;
16            } else {
17              curr.marked = true;
18              pred.next = curr.next;
19              return true;
20            }
21          }
22        } finally {
23          curr.unlock();
24        }
25      } finally {
26        pred.unlock();
27      }
28    }
29  }
```

```
1   private boolean validate(Node pred, Node curr) {
2     return !pred.marked && !curr.marked && pred.next == curr;
3   }
```

验证pred和cur的路径是否可达

contains

```
1    public boolean contains(T item) {
2      int key = item.hashCode();
3      Node curr = head;
4      while (curr.key < key)
5        curr = curr.next;
6      return curr.key == key && !curr.marked;
7    }
```