Coarse-Grained Synchronization

- Ogni metodo opera mediante un lock sull'oggetto
  - Code di attesa per operare sull'oggetto
  - Nozione di correttezza (linearizability)
  - Modello astratto basato sulla nozione di storia
  - Tecniche statiche (+ model checking)
- E' fatta?

1

Coarse-Grained Synchronization

- Operare con thread
  - Non aumenta necessariamente l'efficienza complessiva di un sistema
  - Attese attive, overhead di gestione, run-time complicato,
- Multiprocessori?
  - Alcune app sono inerentemente parallele … map&reduce come usato da Google

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Fine-Grained Synchronization

- Non utilizziamo un lock globale …
- Strutturiamo l'oggetto in un insieme di lock
  - Independently-synchronized components
- Metodi sono in conflitto quando cercano di accedere
  - Medesima componente…
  - contemporaneamente

Optimistic Synchronization

- Si cerca la componente richiesta senza usare lock…
- Una volta trovata …
  - OK: e' fatta
  - Oops: riprova
- Valutazione
  - Semplice
  - Errori di programmazione sono costosi

Interface: Set

- Metodi
  - add(x)
  - remove(x)
  - contains(x)

List-Based Sets

```
public interface Set<T> {
 public boolean add(T x);
 public boolean remove(T x);
 public boolean contains(T x);
}
```

List Node

```
public class Node {
 public T item;
 public int key;
 public Node next;
}
```

List Node

```
public class Node {
 public T item;
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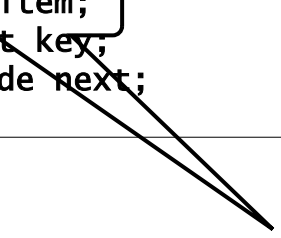
 public Node next;
}
```



Contenuto informativo

List Node

```
public class Node {
 public T item;
 public int key;
 public Node next;
}
```

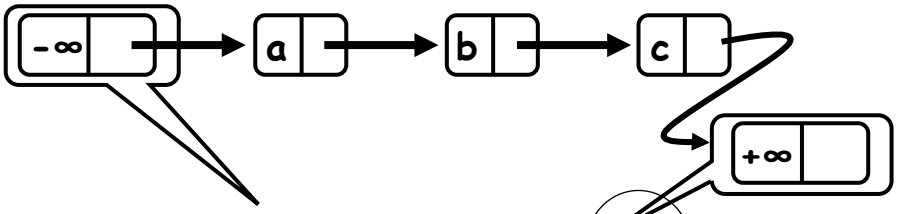
Chiave di ricerca

List Node

```
public class Node {
 public T item;
 public int key;
 public Node next;
}
```

Riferimento al prossimo elemento

List-Based Set



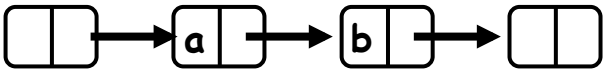
Ordinata con sentinelle
(chiavi min & max)

Invariante …

- Preservato da
  - `add()`
  - `remove()`
  - `contains()`
- Solita induzione sulla struttura

Funzione di astrazione

- Rep:



- Astrattamente:
  - {**a**, **b**}

Rep Invariant

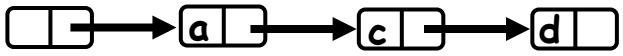
- Rep invariant
  - Definisce quali sono le rappresentazioni legali "valide"
  - Preservato dai metodi
  - Dipende dai metodi

Abstraction Function

- alpha(head) =
  - { x | esiste a tale che
    - a raggiungibile da head e
    - a.item = x
  - }

List Based Set

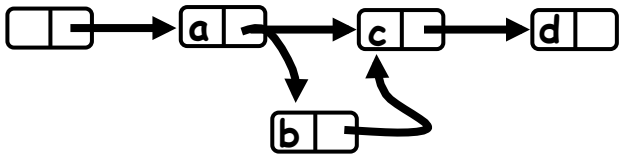
Add(b)



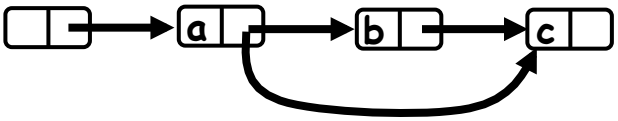
Remove(b)

List Based Set

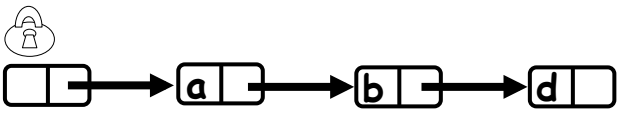
Add(b)



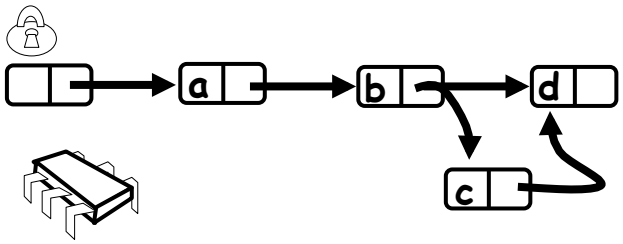
Remove(b)



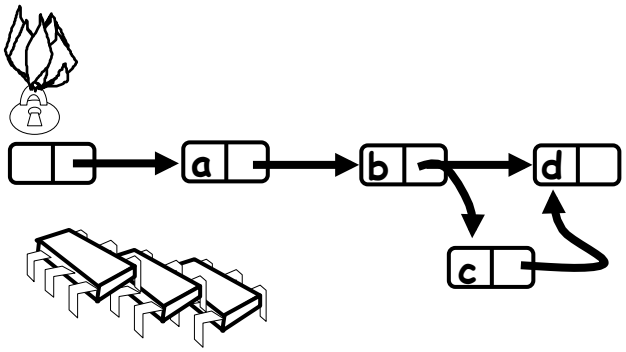
Coarse-Grained Locking



Coarse-Grained Locking



Coarse-Grained Locking



Semplice e costoso

Coarse-Grained Locking

- Metodi sincronizzati (a la Java)
  - "Solo un metodo ha l'accesso …"
- Corretto
- Thread multipli
  - Code di attesa
  - Overhead

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Fine-grained Locking

- Pensare prima di programmare a testa bassa
- Suddividere l'oggetto in parti
  - Ogni parte dell'oggetto ha un suo lock
  - Metodi che operano su parti disgiunte possono operare senza problema di sincronizzazione

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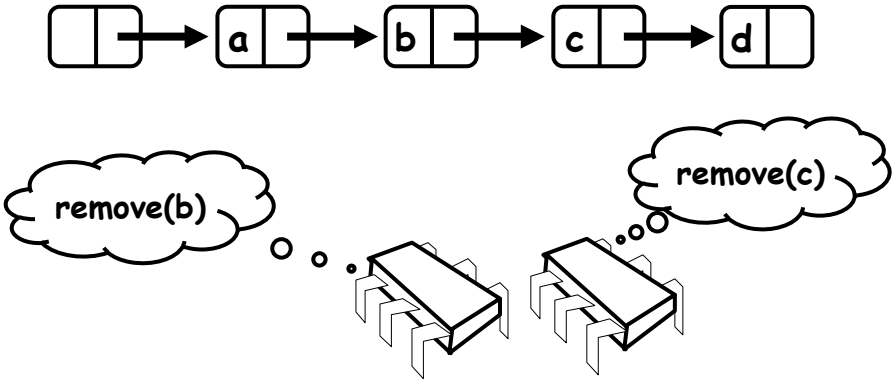
Concurrent Remove



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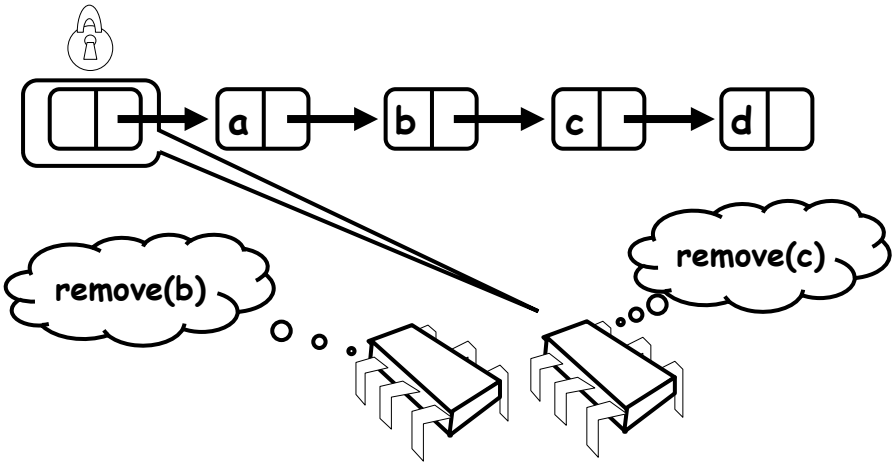

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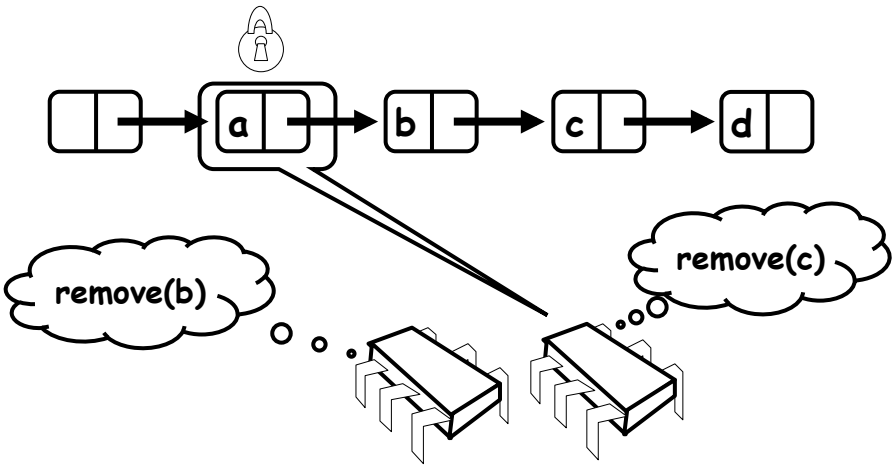

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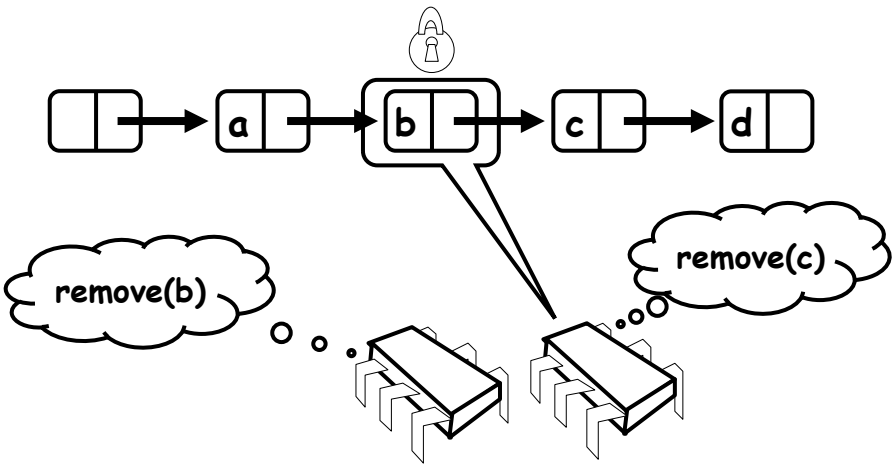

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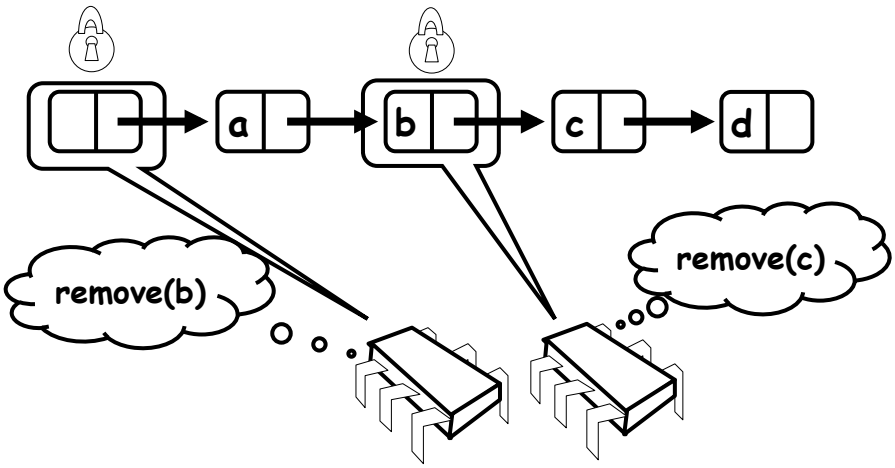

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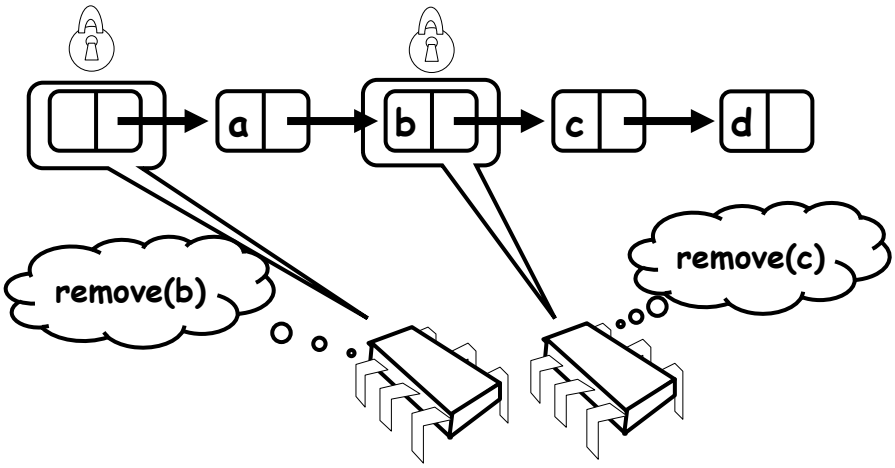

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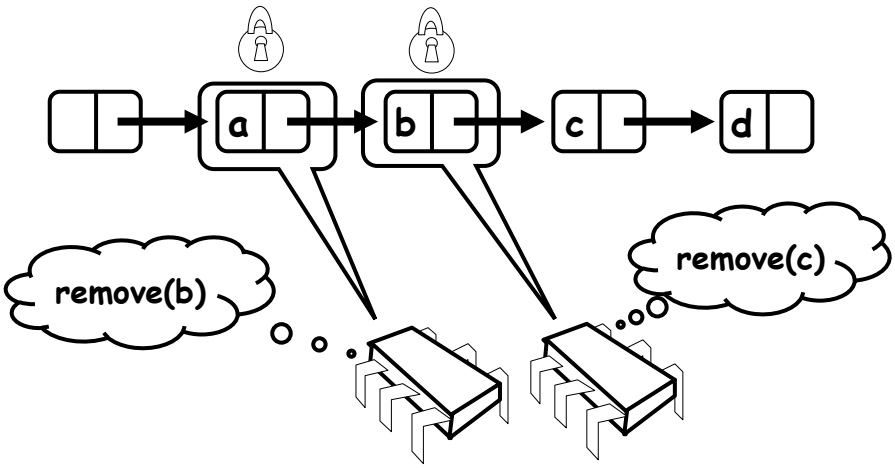

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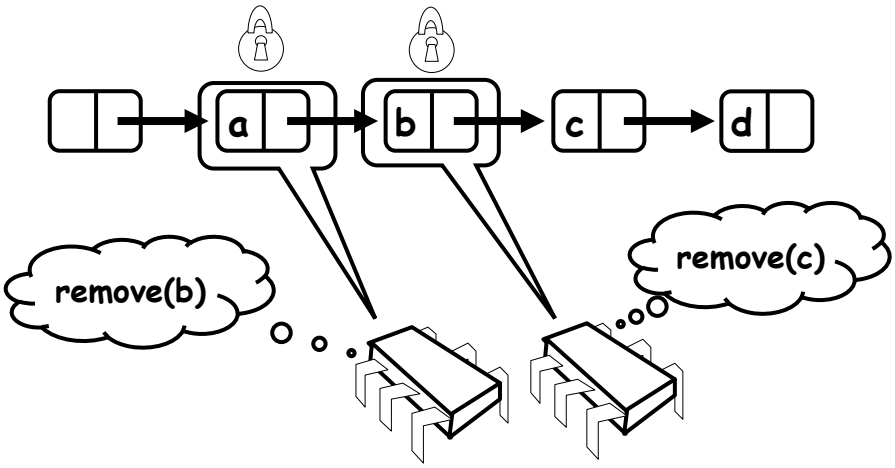

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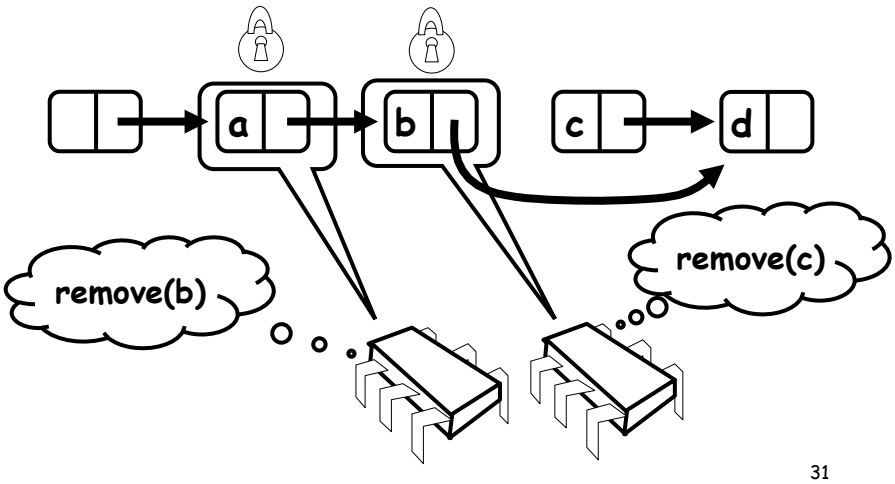

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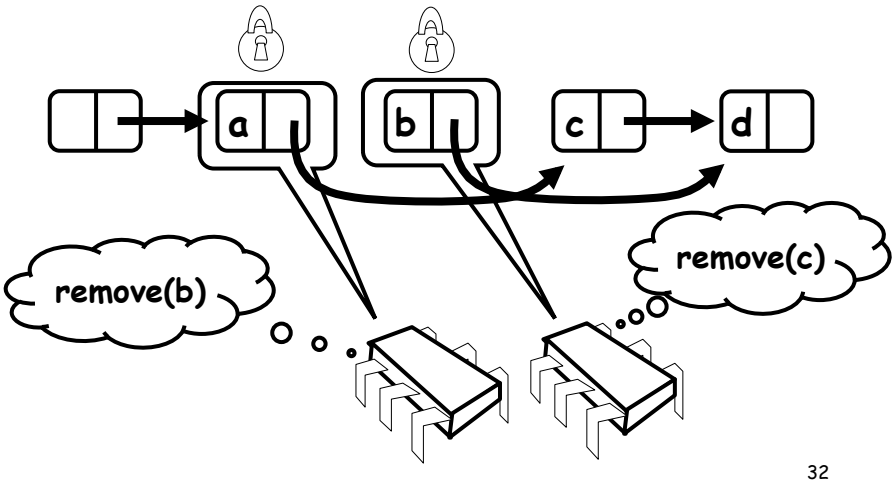
Concurrent Remove



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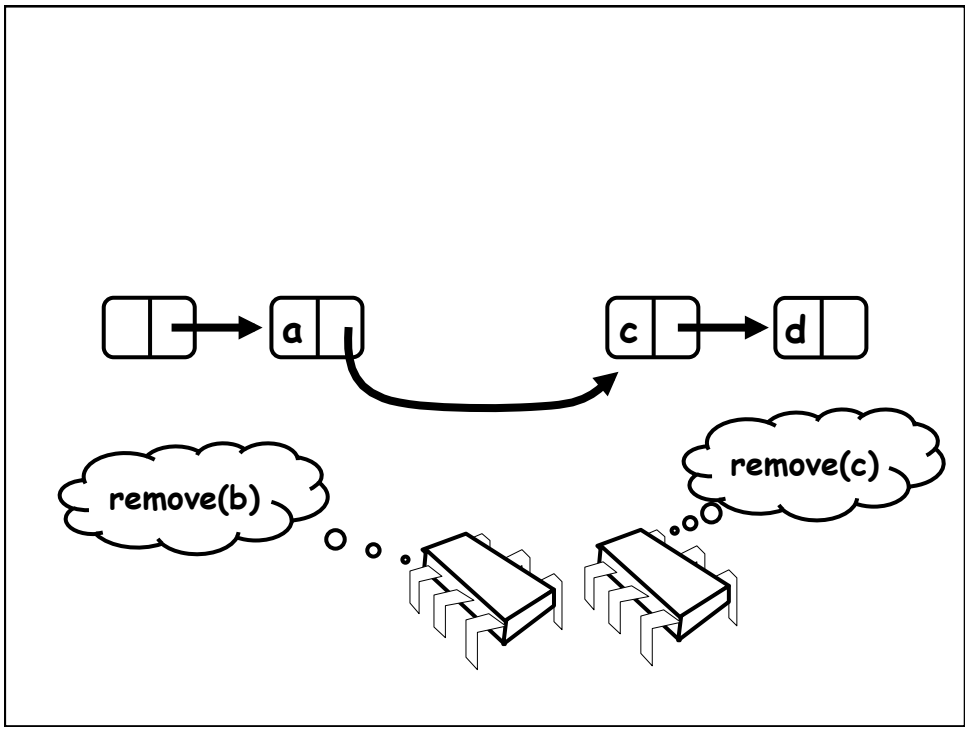
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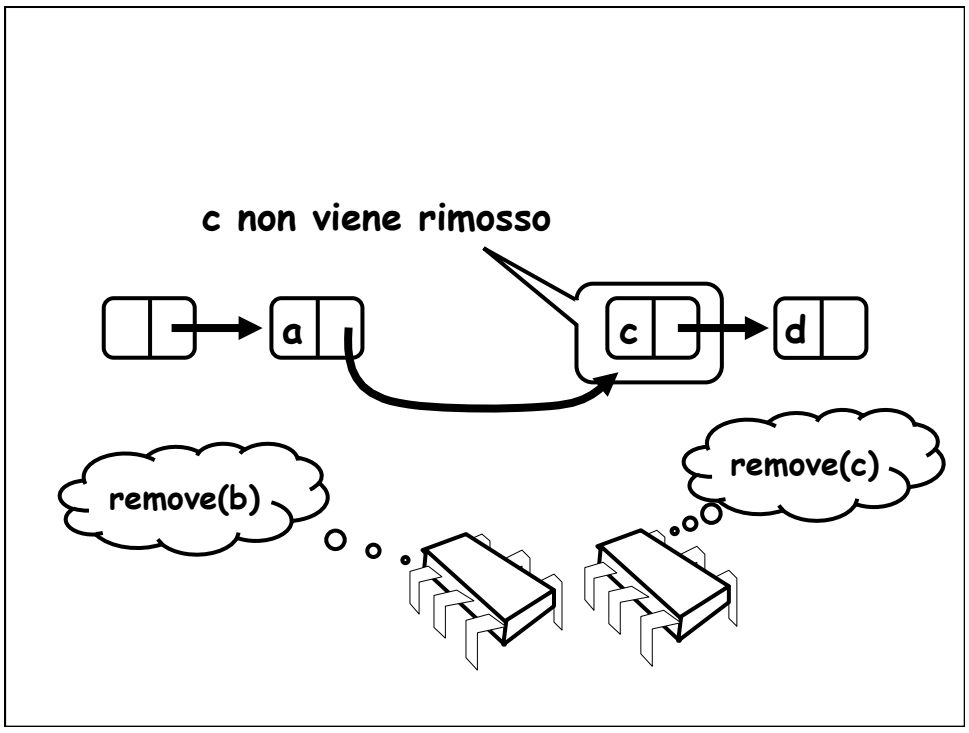
remove(b)
remove(c)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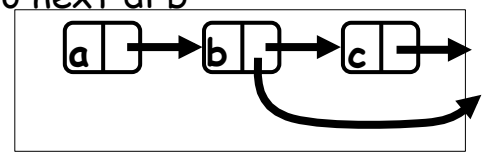
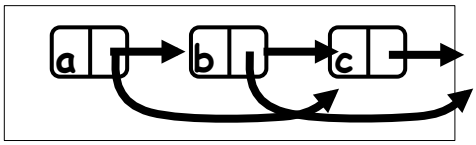
Quale e' il problema?

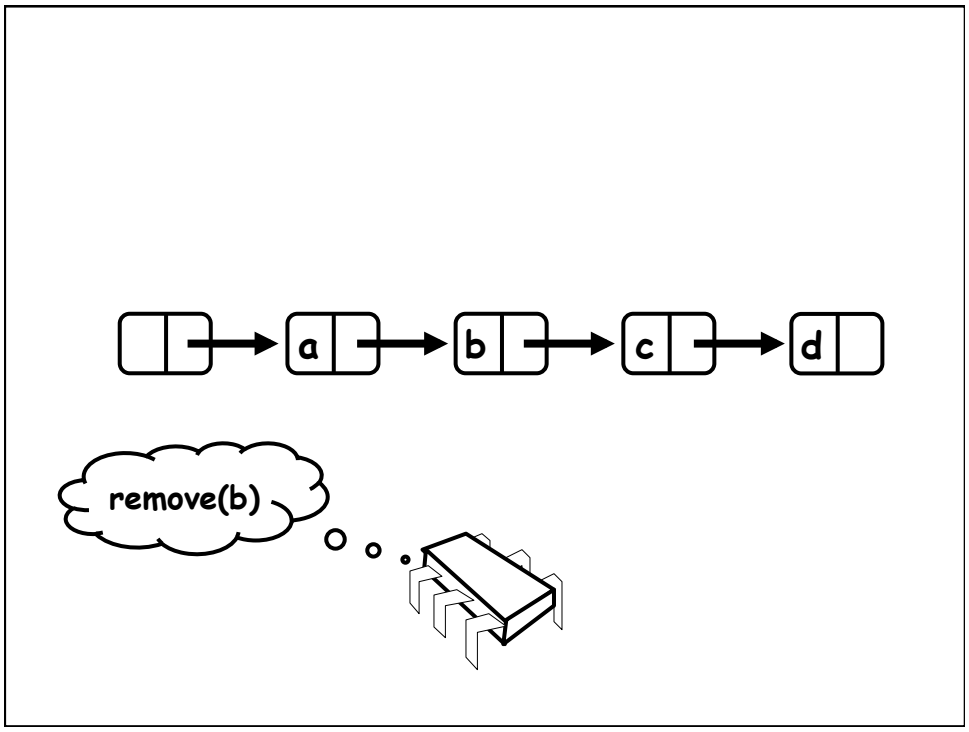
- Rimuovere c
  - Operare sul campo next di b





Cerchiamo di capire il problema

- Se un nodo e' "lock"
  - Nessuno puo cancellare il nodo *successore*
- Morale: il thread deve fare il lock
  - Sul nodo da cancellare
  - E sul predecessore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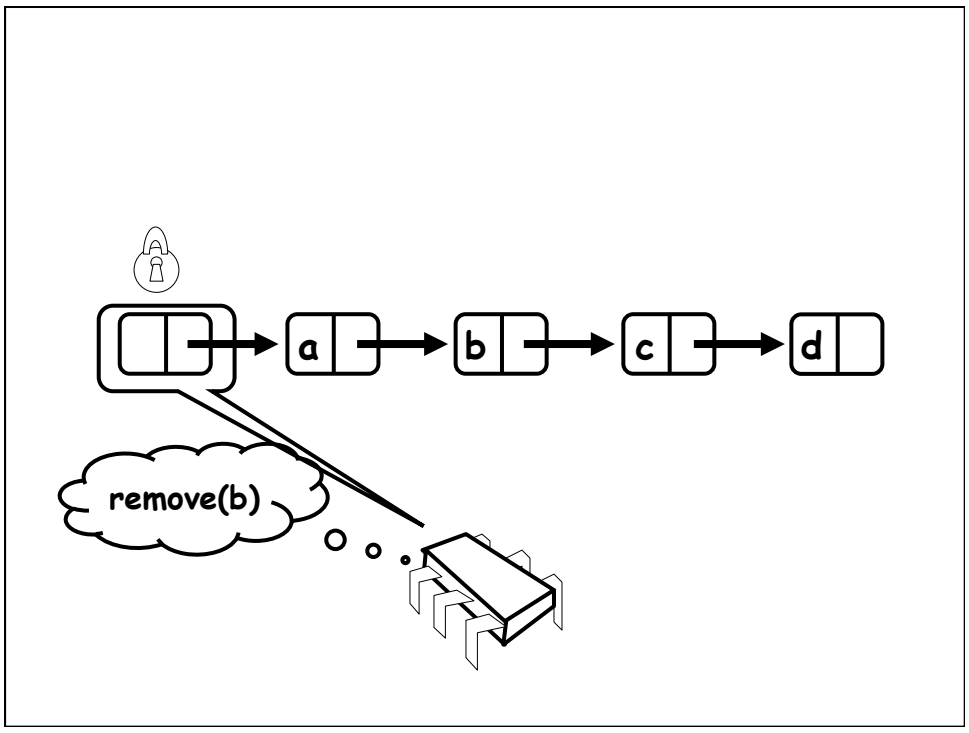
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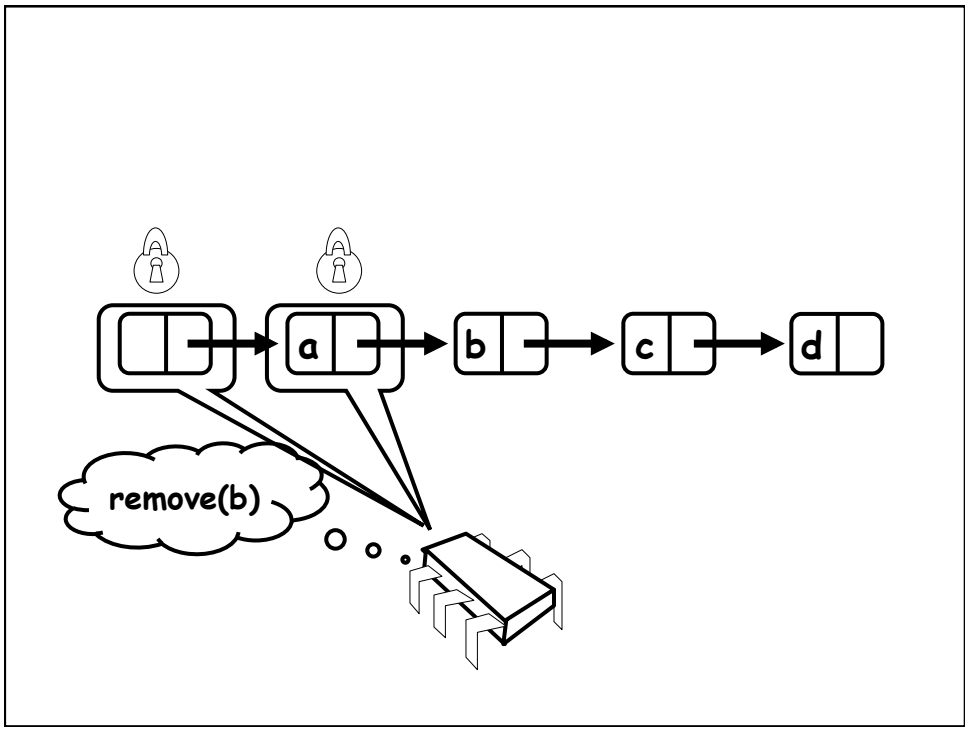
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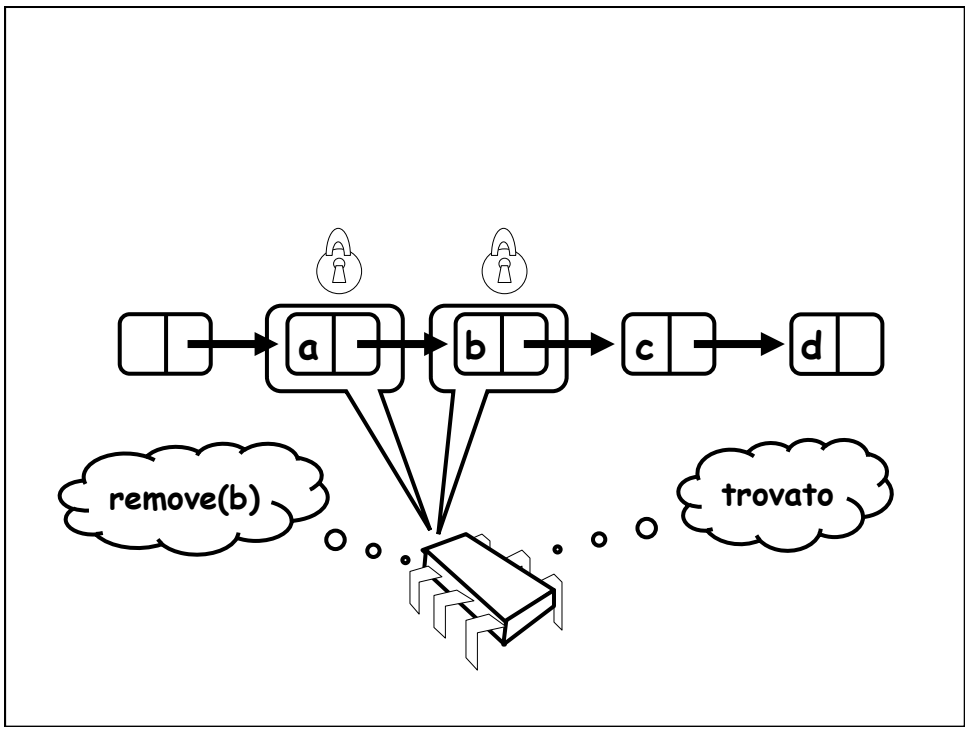
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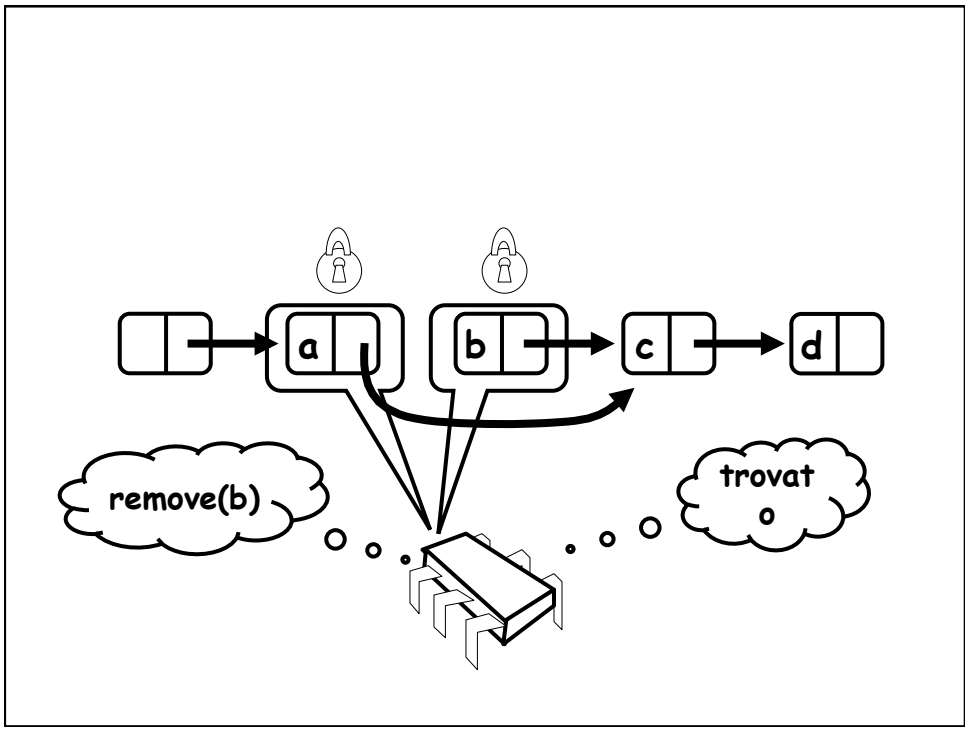
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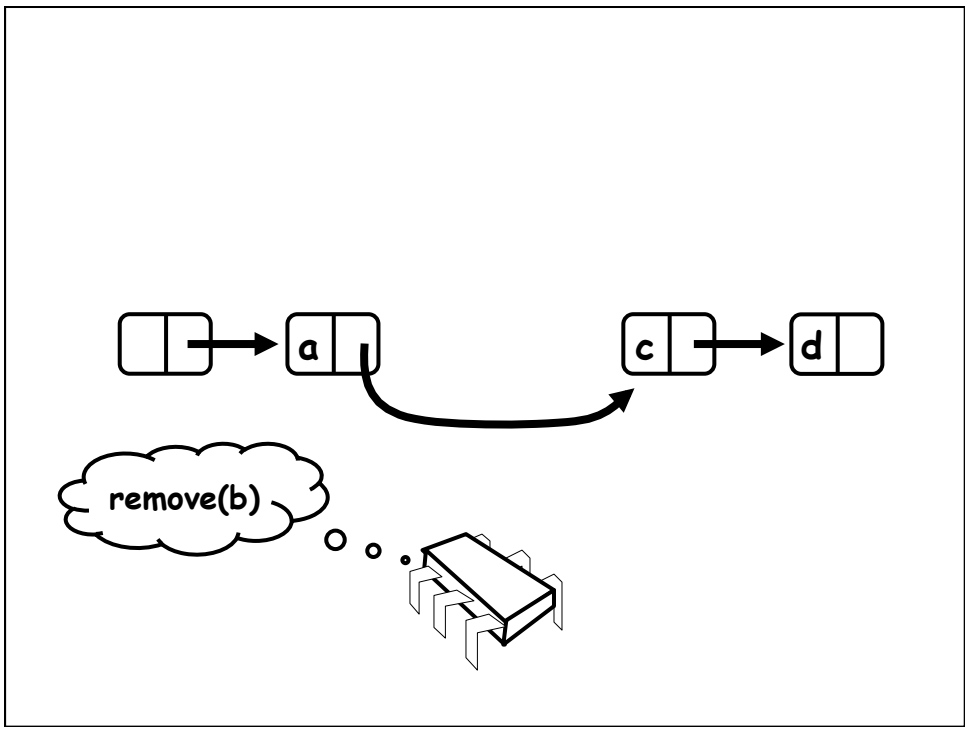
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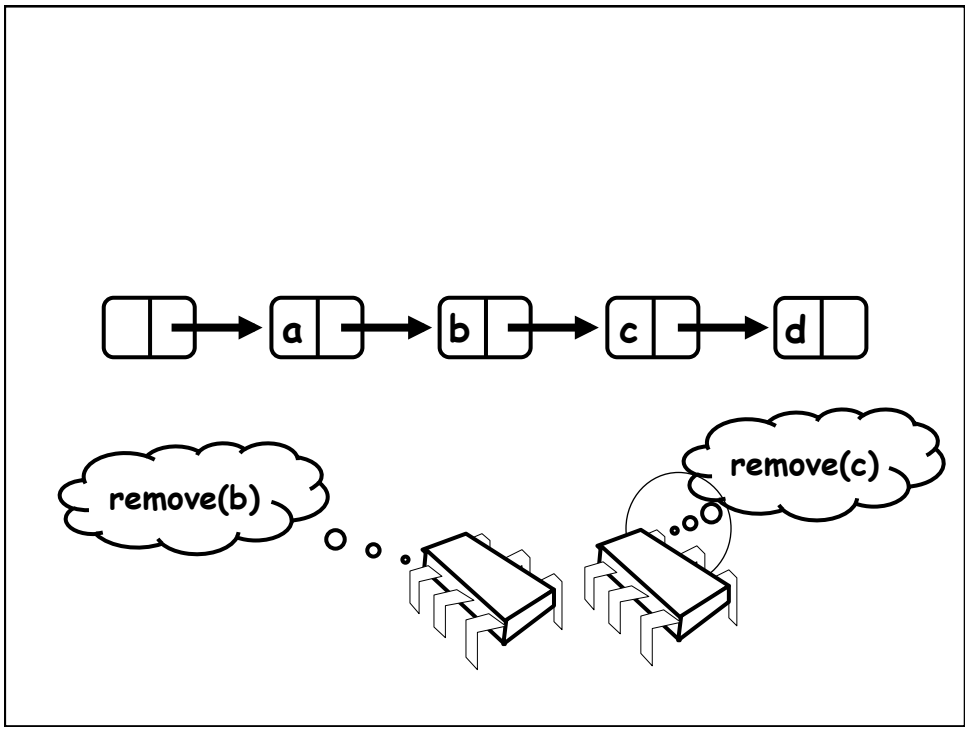
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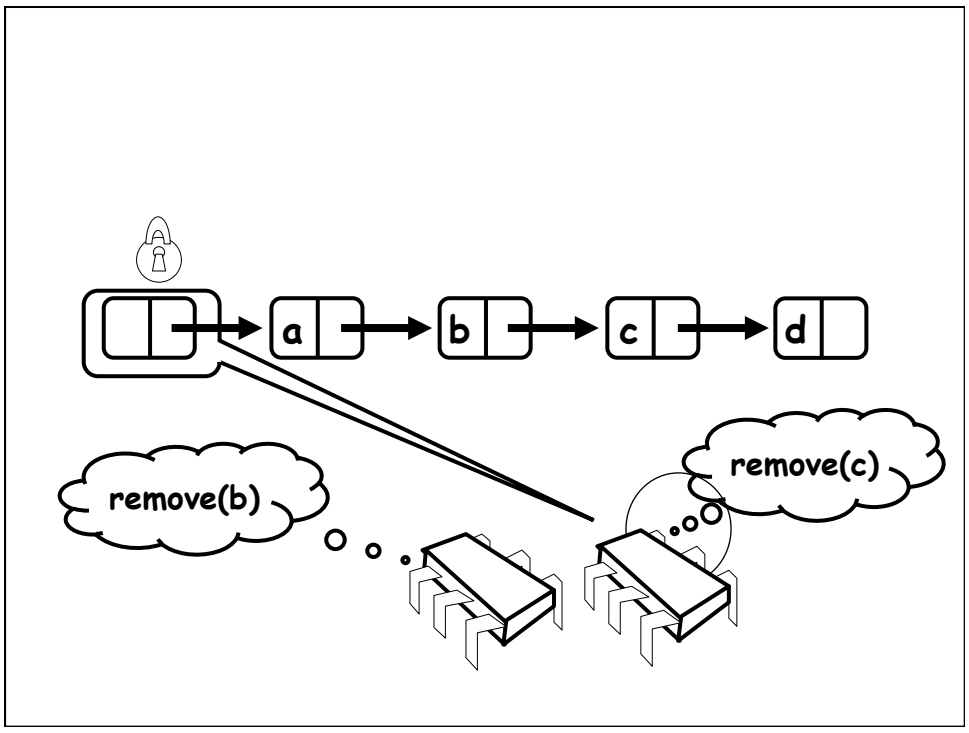
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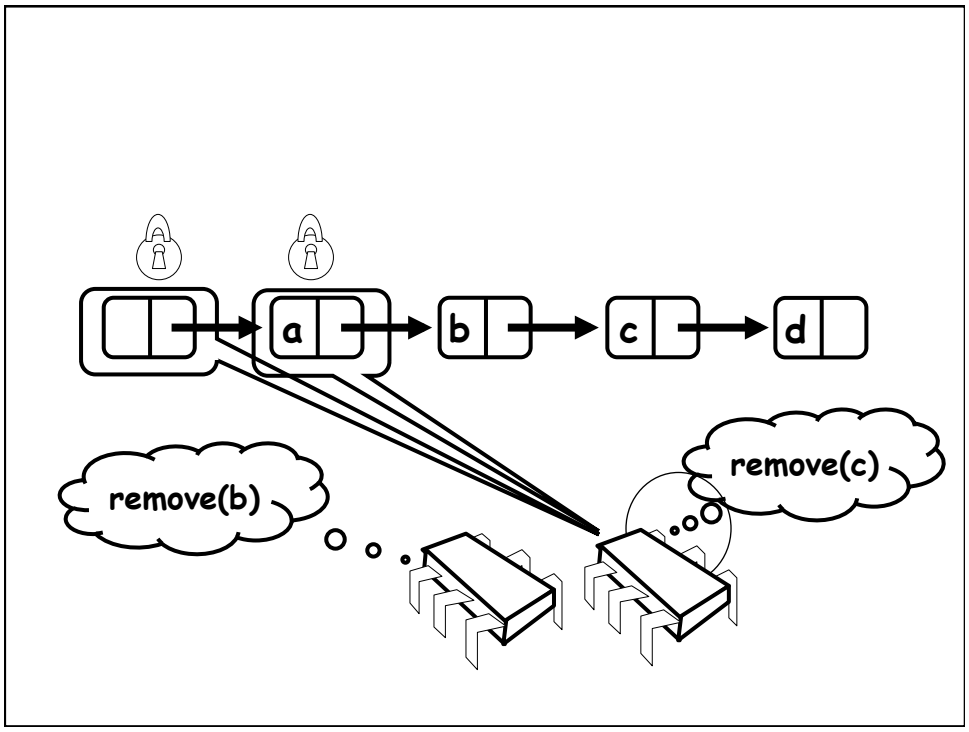
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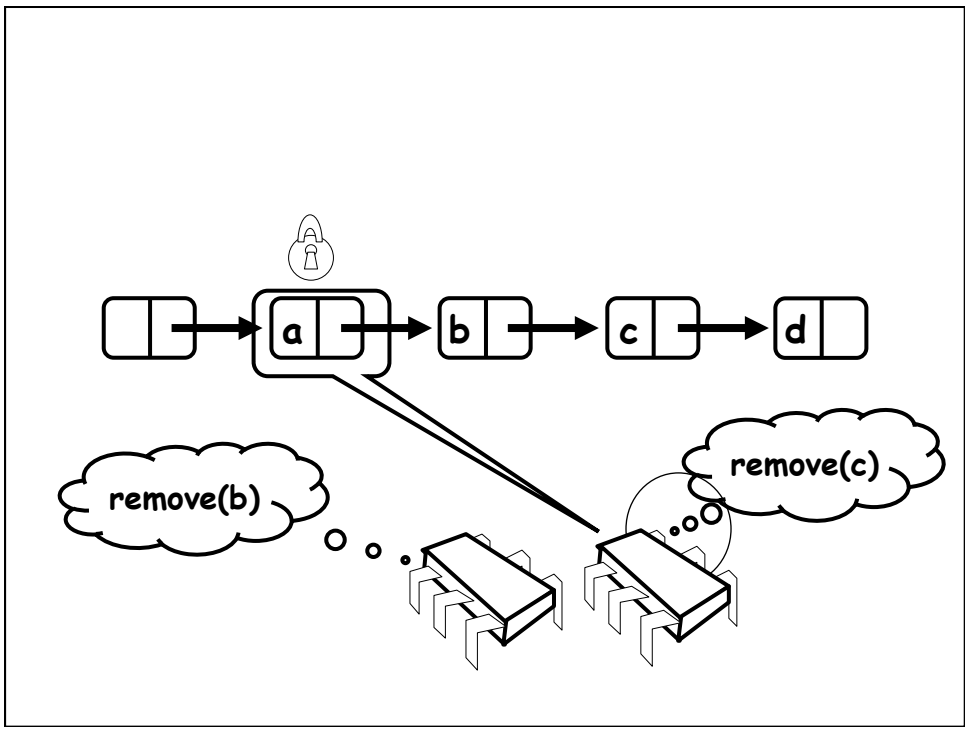
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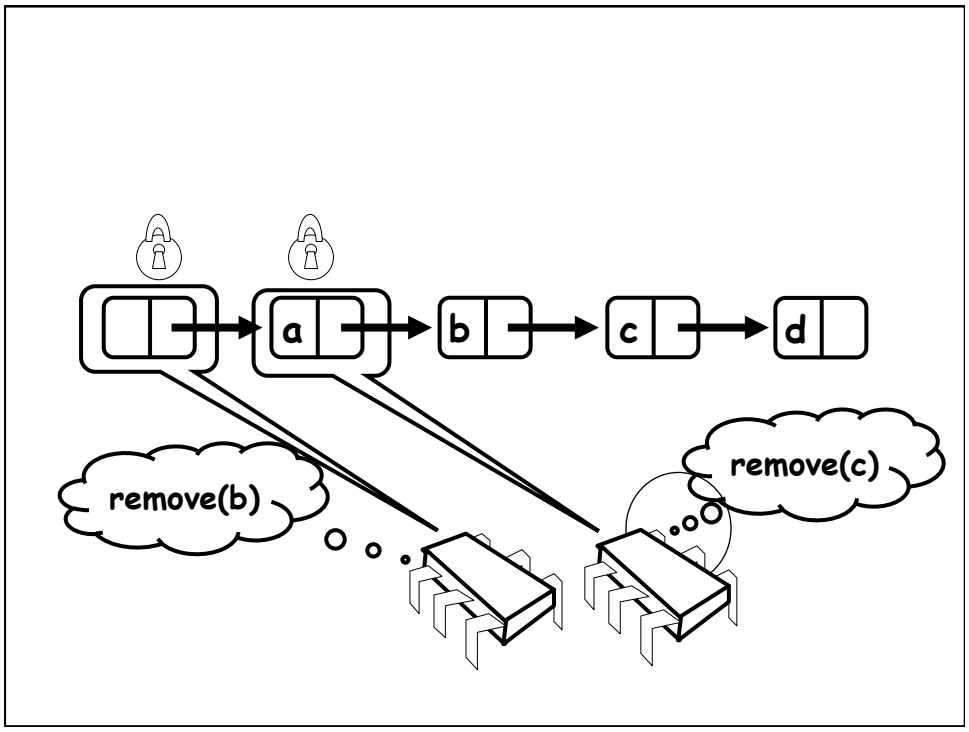
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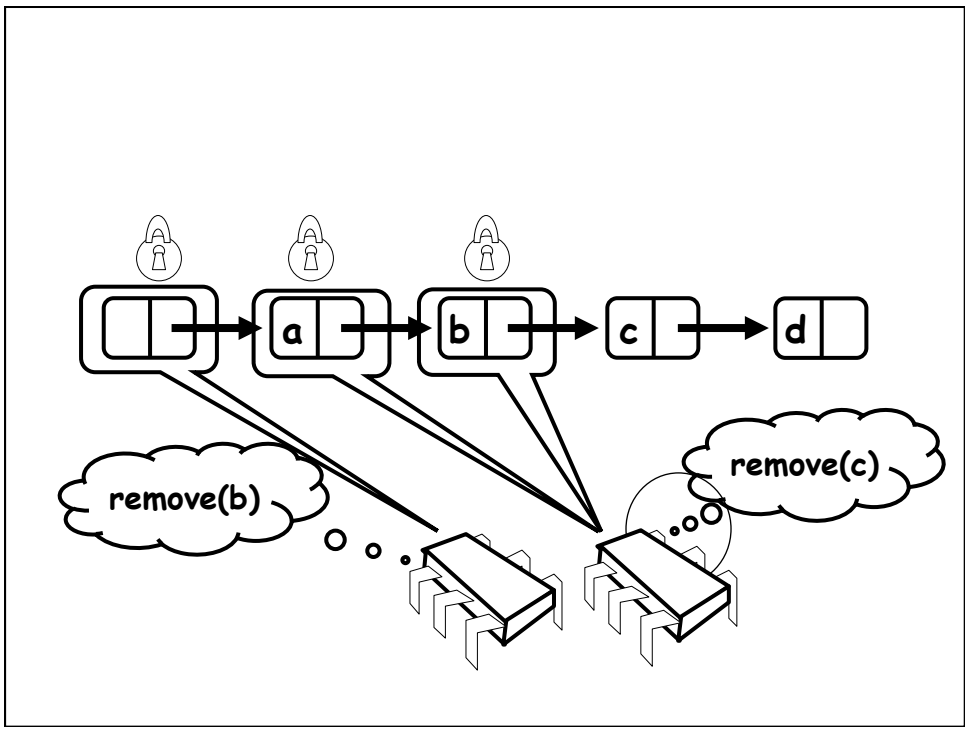
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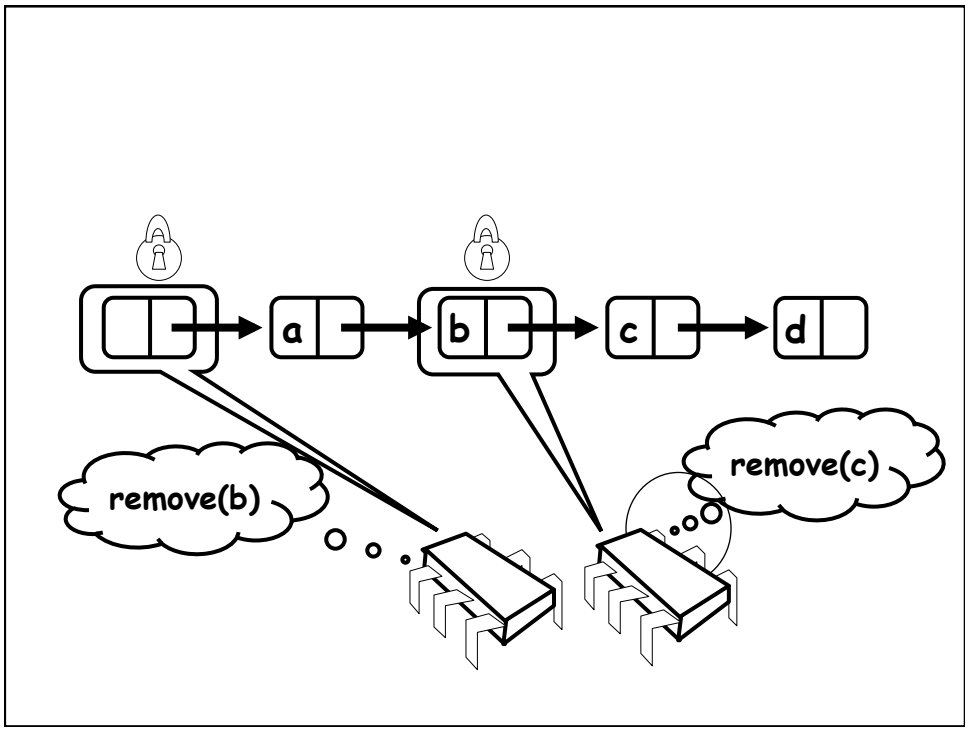
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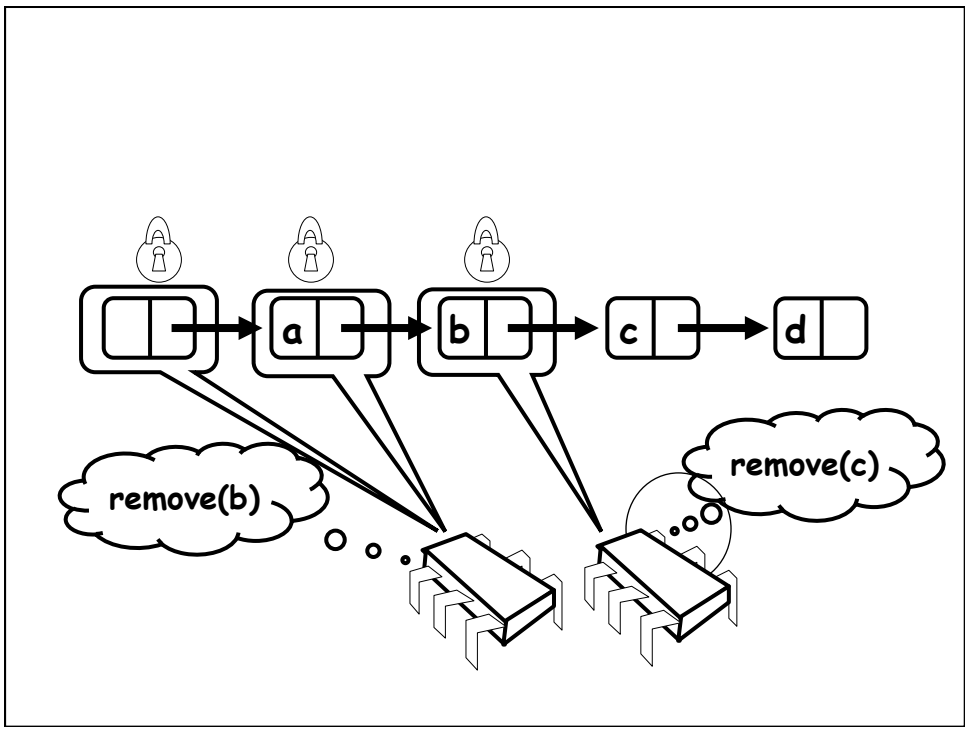
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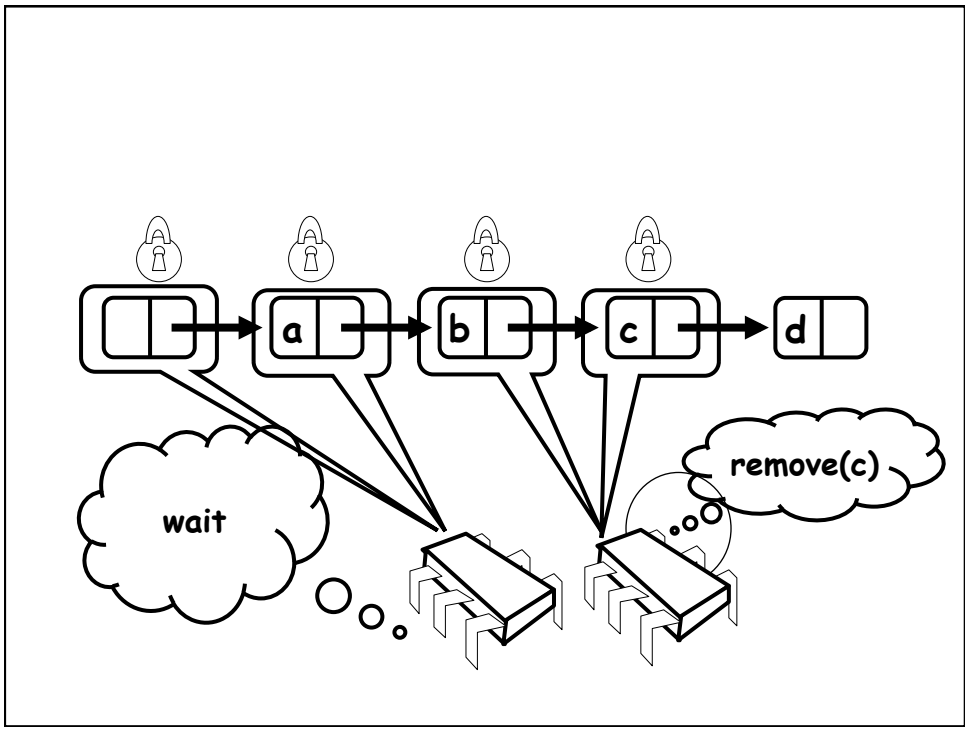
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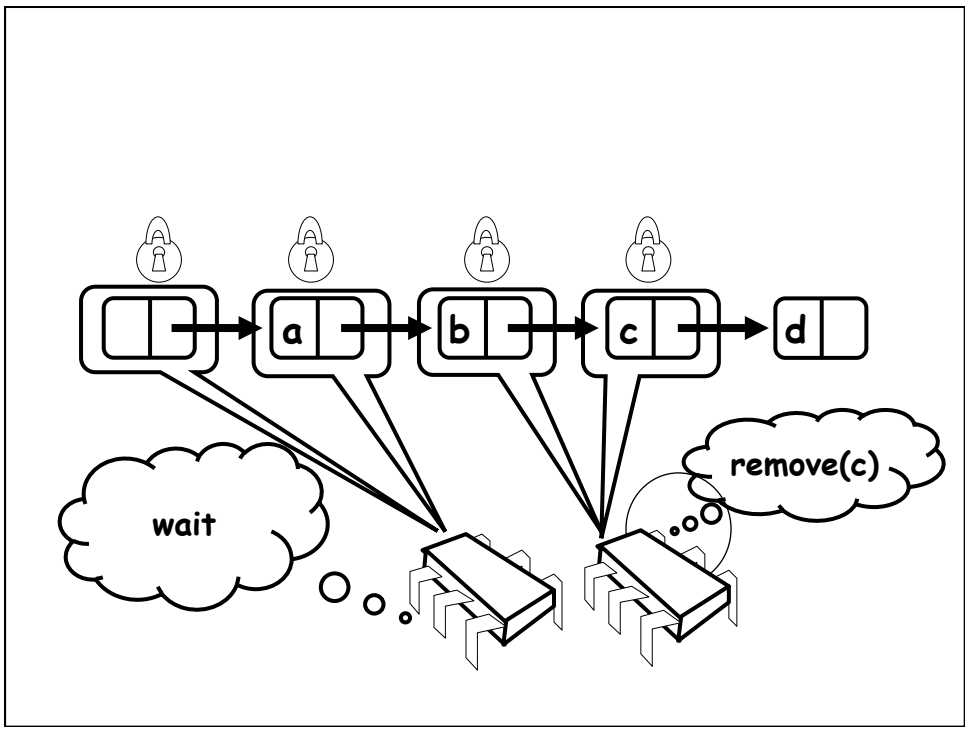
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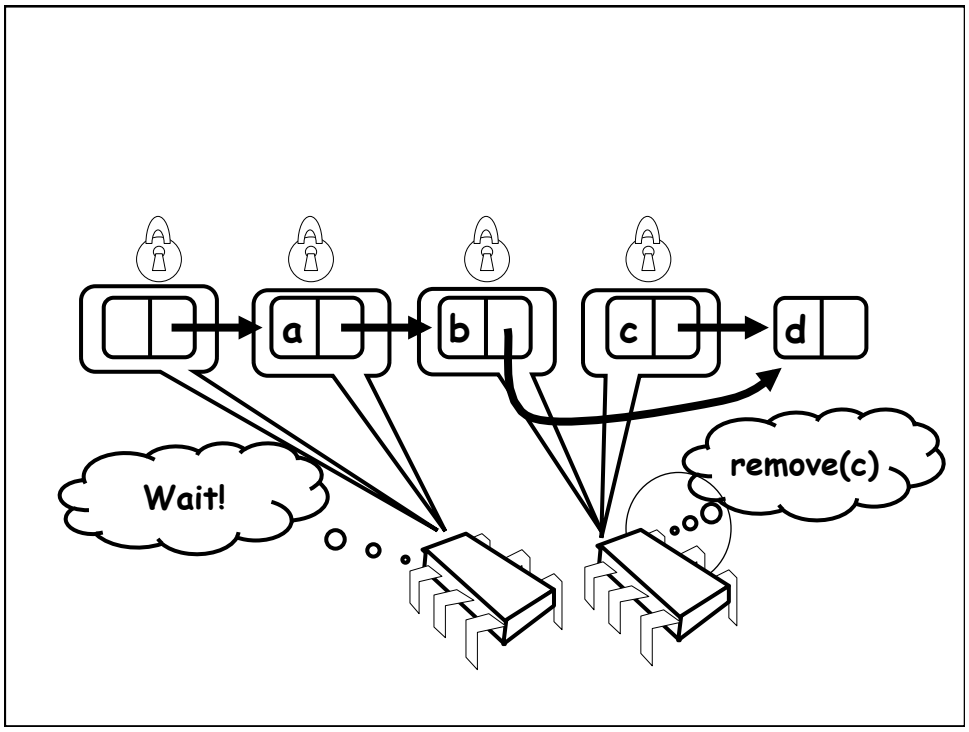
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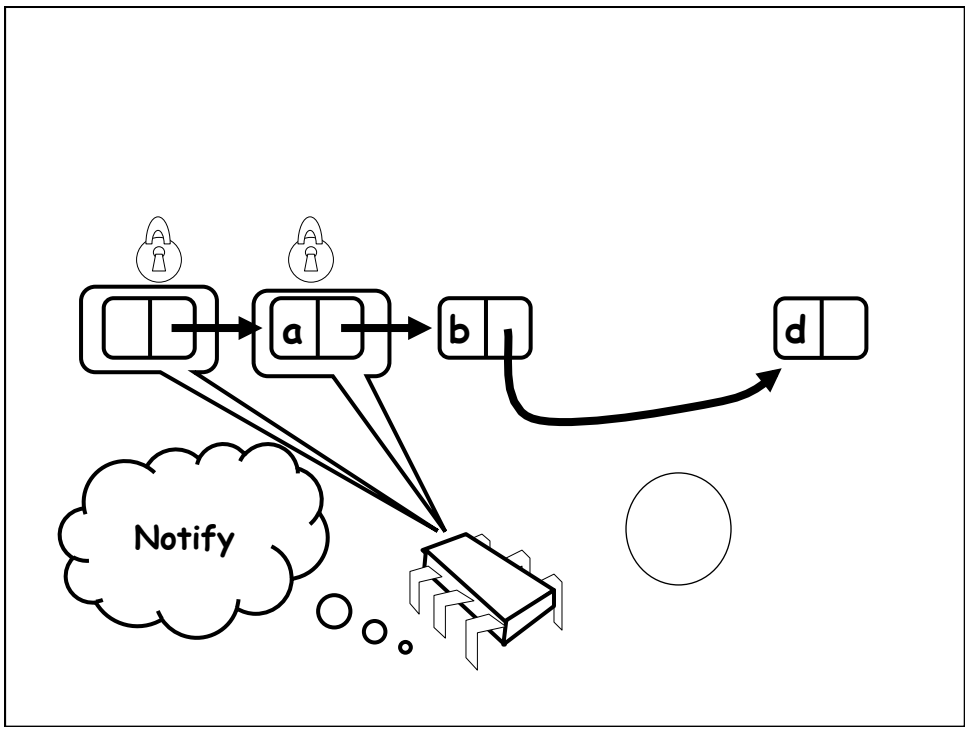
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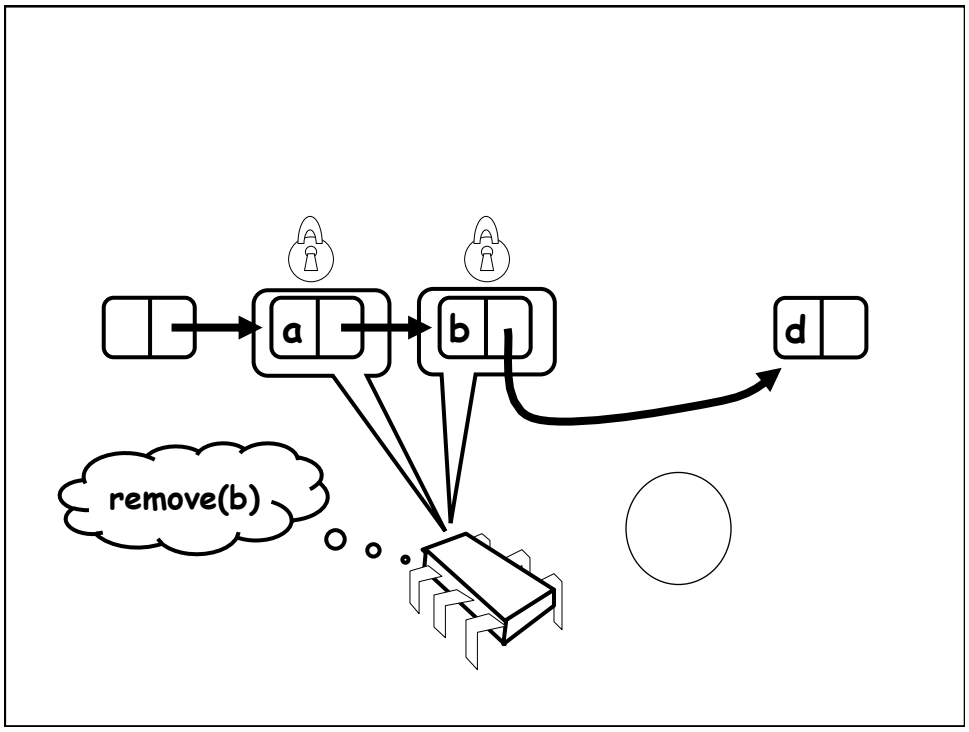
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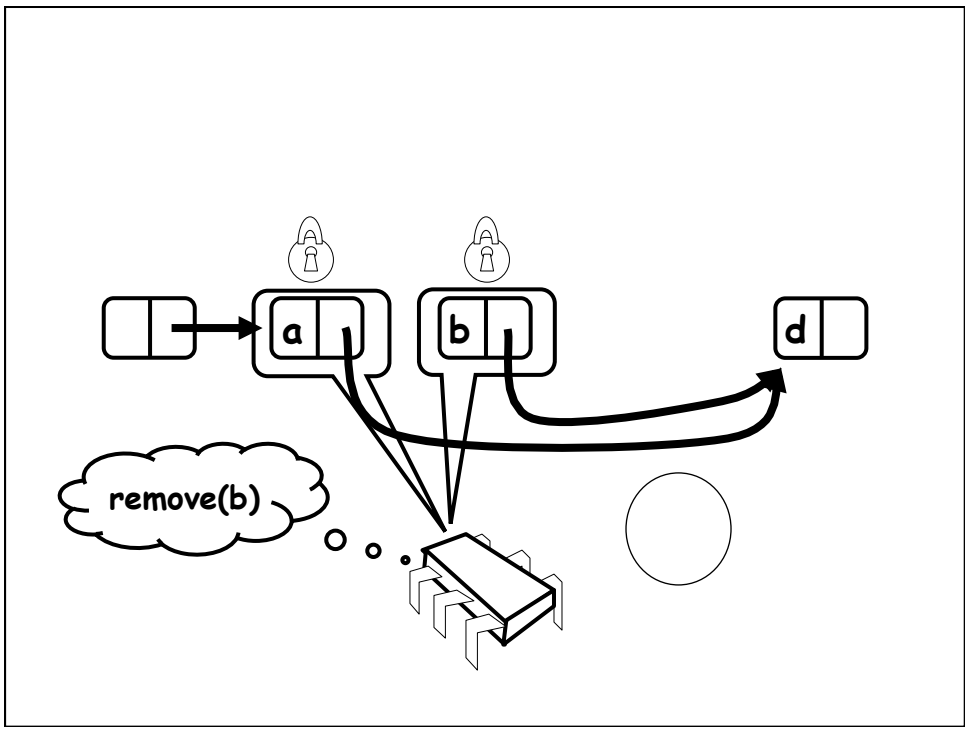
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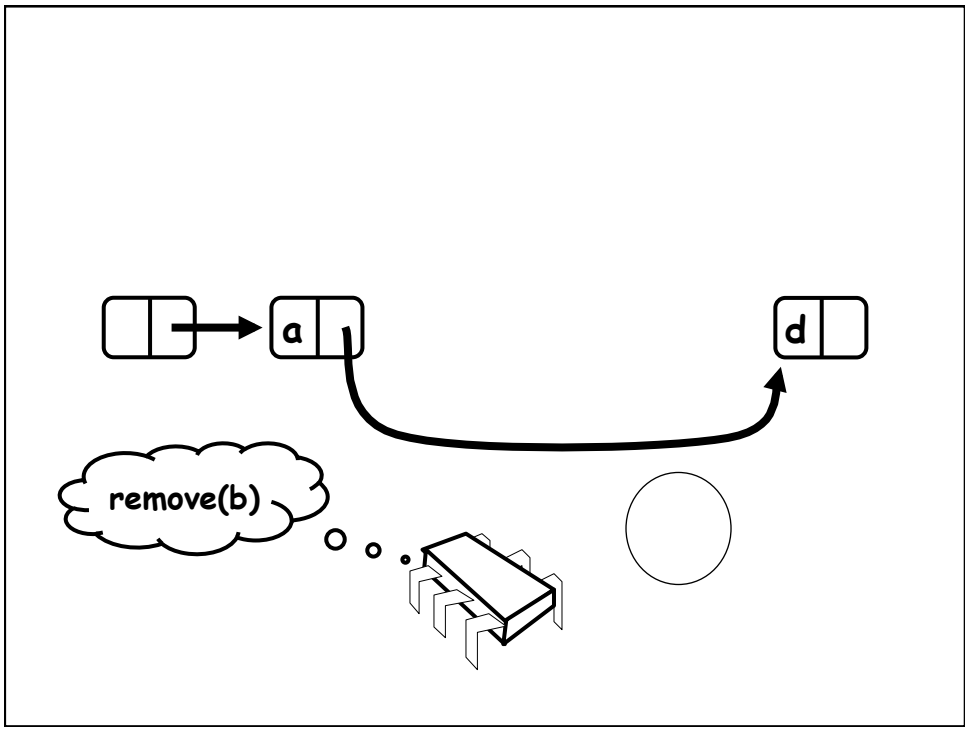
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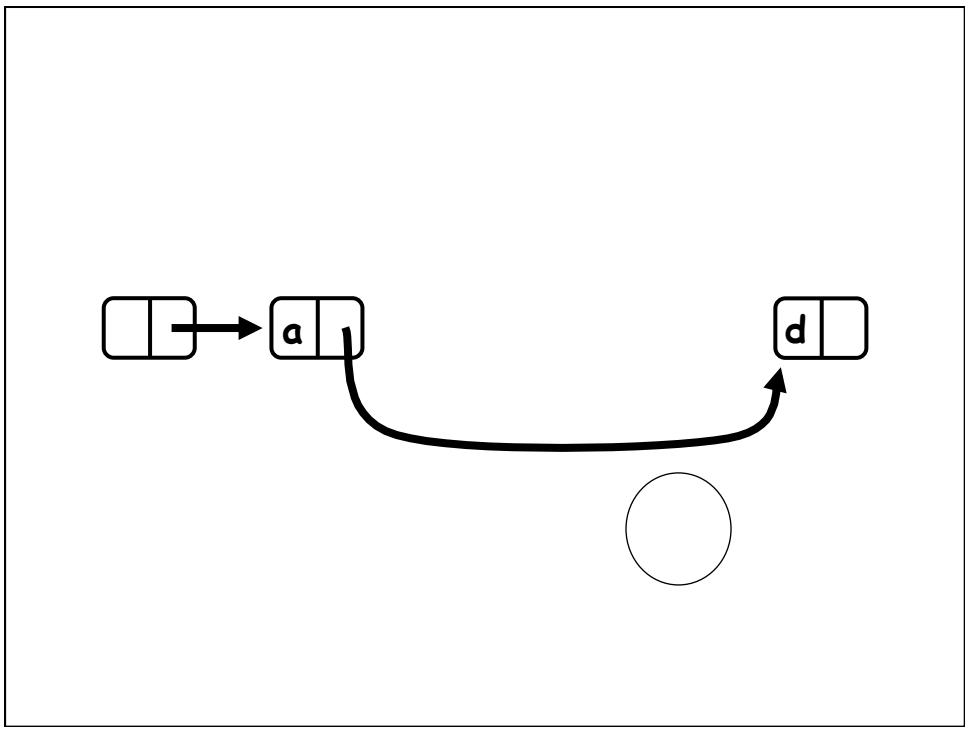
a
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Remove method

```
public boolean remove(Item item) {
 int key = item.hashCode();
 Node pred, curr;
 try {
   …
 } finally {
  curr.unlock();
  pred.unlock();
 }}
```

Remove method

```
public boolean remove(Item item) {
 int key = item.hashCode();
 Node pred, curr;
 try {
   …
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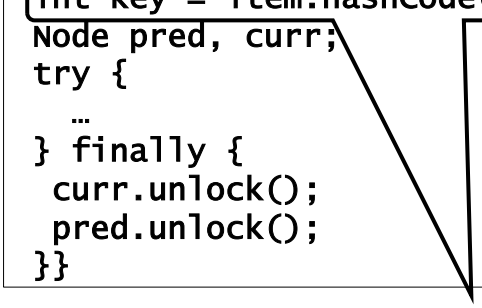


Chivi ordinate per la ricerca

Remove method

```
public boolean remove(Item item) {
 int key = item.hashCode();
 Node pred, curr;
 try {
   …
 } finally {
  currNode.unlock();
  predNode.unlock();
 }}
```

Predecessor e current

Remove method

```
public boolean remove(Item item) {
 int key = item.hashCode();
 Node pred, curr;
 try {
   …
 } finally {
  curr.unlock();
  pred.unlock();
 }}
```

Rilasciare Il lock!!

Remove method

```
public boolean remove(Item item) {
 int key = item.hashCode();
 Node pred, curr;
 try {
   …
 } finally {
  curr.unlock();
  pred.unlock();
 }}
```

ops

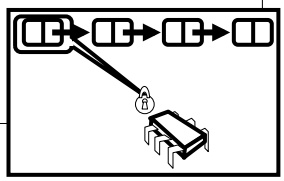
Remove method

```
try {
 pred = this.head;
 pred.lock();
 curr = pred.next;
 curr.lock();
 …
} finally { … }
```

Remove method

lock pred == head

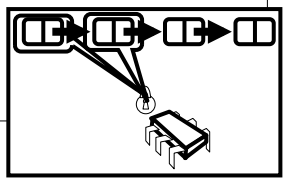
```
try {
 pred = this.head;
 pred.lock();
 curr = pred.next;
 curr.lock();
 …
} finally { … }
```



Remove method

Lock current

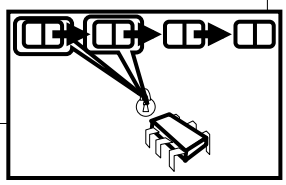
```
try {
 pred = this.head;
 pred.lock();
 curr = pred.next;
 curr.lock();
 …
} finally { … }
```



Remove method

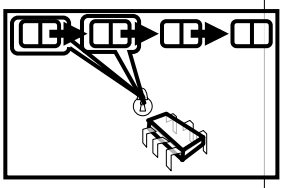
```
try {
 pred = this.head;
 pred.lock();
 curr = pred.next;
 curr.lock();
 …
} finally { … }
```

Muoversi sulla lista



Remove: searching

```
while (curr.key < key) {
  pred.unlock();
  pred = curr;
  curr = curr.next;
  curr.lock()
  }
  if (key == curr.key) {
   pred.next = curr.next;
   return true;
  }
;
 }
 return false;
```



Funziona?

- Per eliminare il nodo e
  - Effettuare il lock su e
  - Deve esssre presente il lock sul predecessore del nodo e
- Se questo avviene puo' essere eliminato

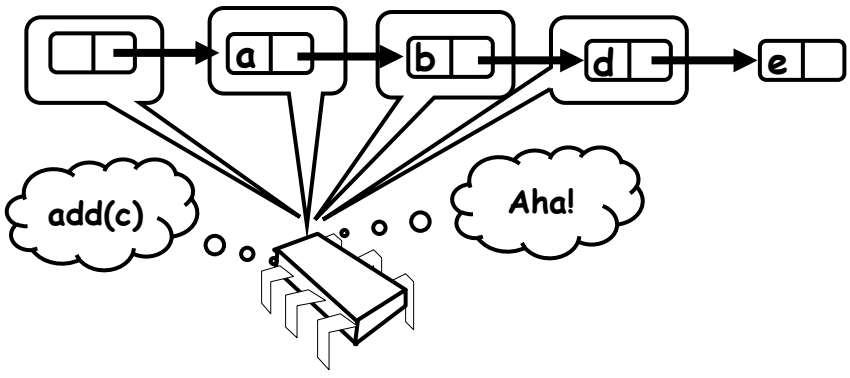
Inserzione

- Add e
  - lock predecessor
  - lock successor

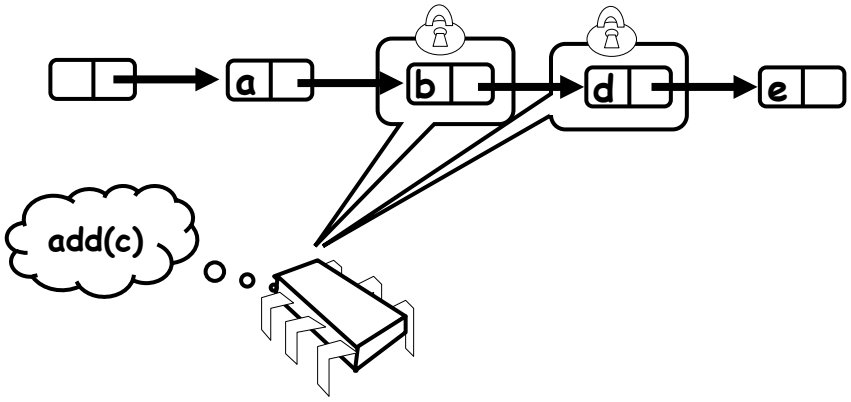
Tutto bene?

- Sicuramente meglio del lock globale
  - Thread possono scorrere in parallelo
- Comportamento ideale?
  - Catena di lock/unlock
  - Potrebbe non essere efficiente

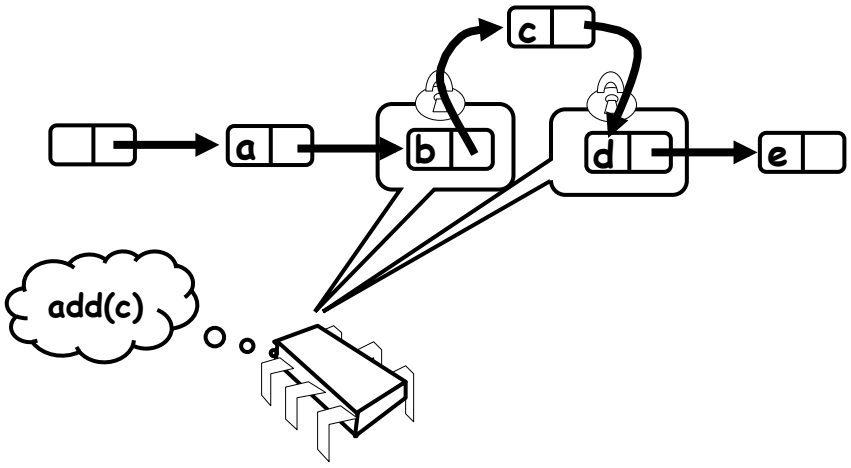
Optimistic: scorrere senza fare Lock



Optimistic



Optimistic



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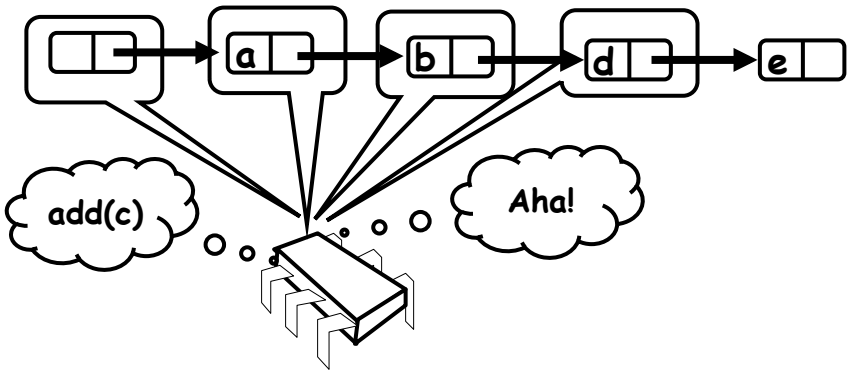
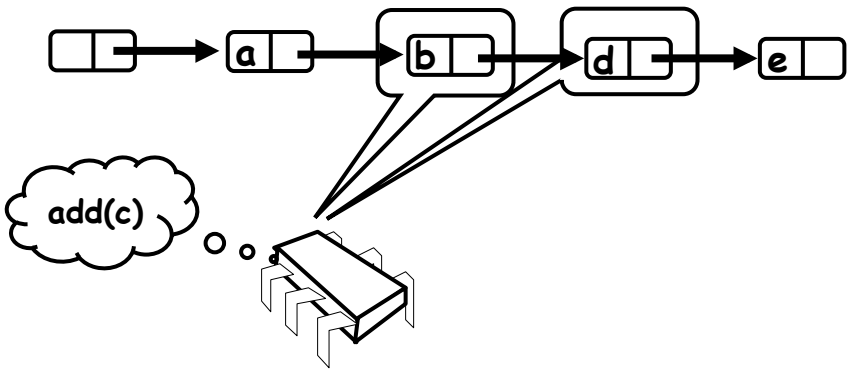
Cosa potrebbe andare storto?



Cosa potrebbe andare storto?



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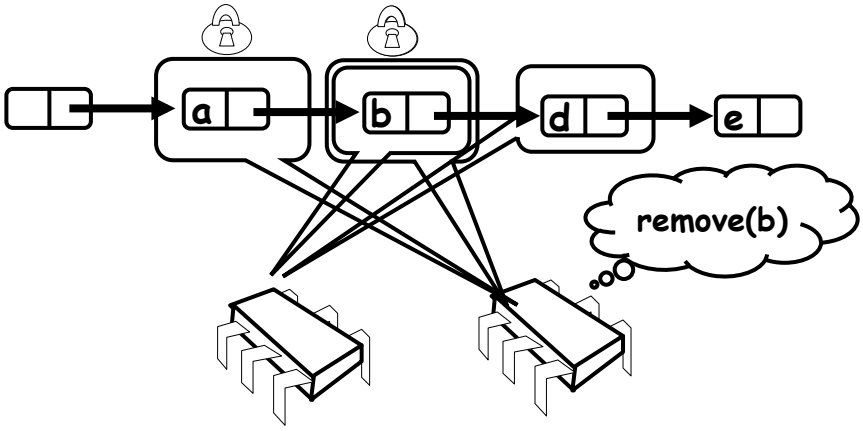
Cosa potrebbe andare storto?



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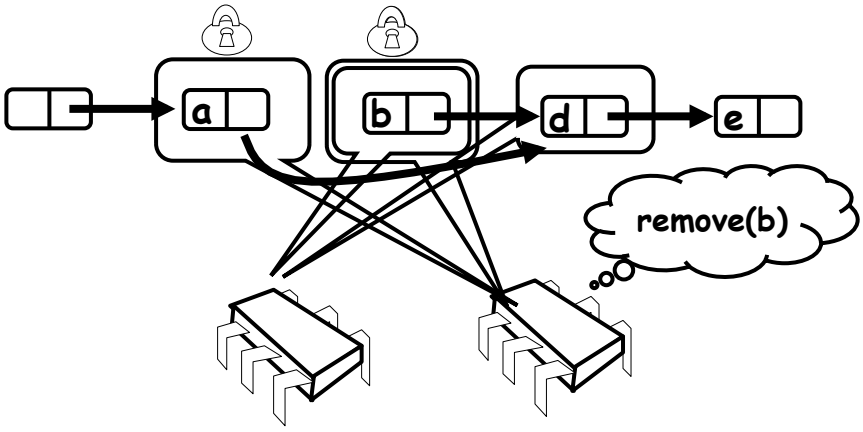
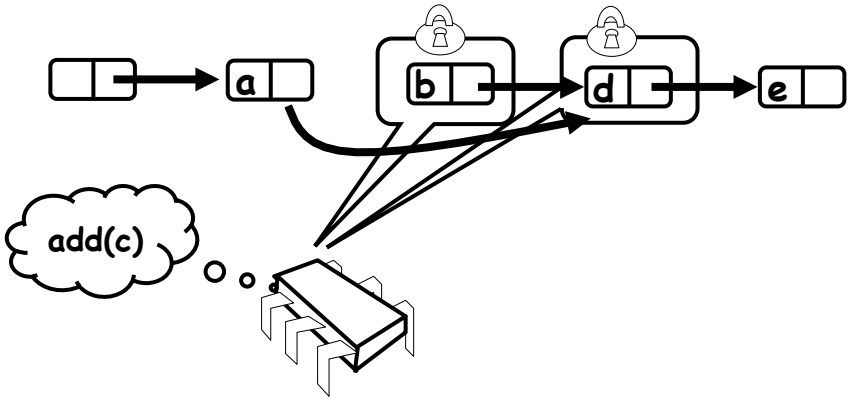
Cosa potrebbe andare storto?



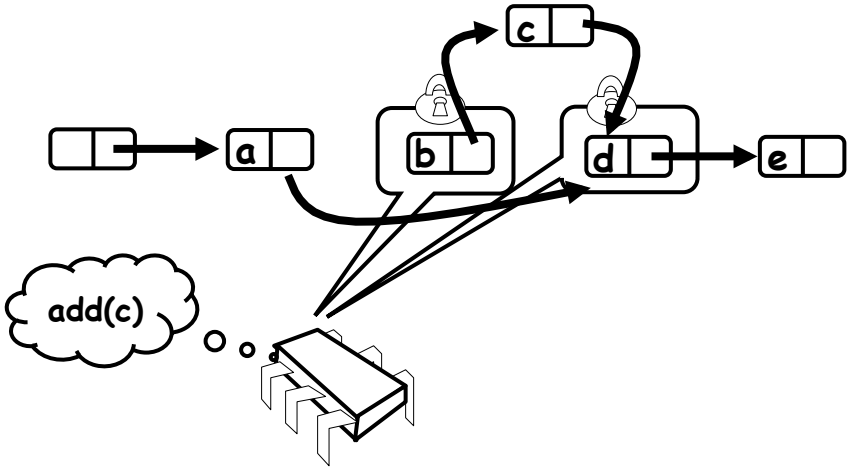
78

Cosa potrebbe andare storto?



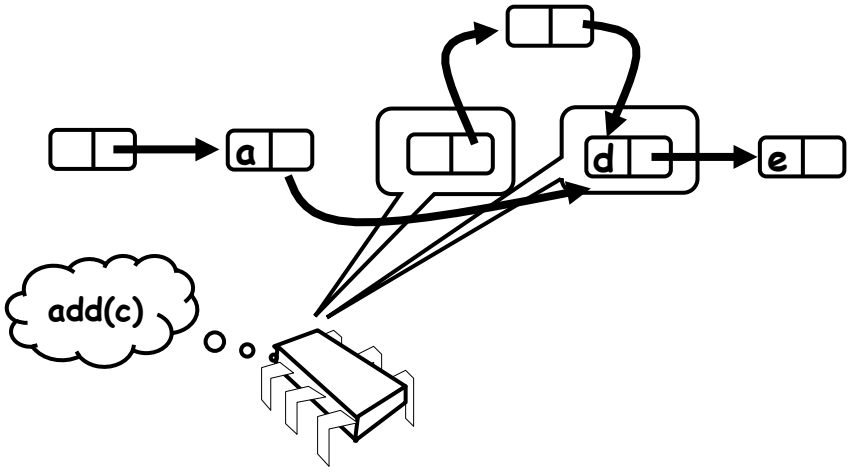
79

Cosa potrebbe andare storto?

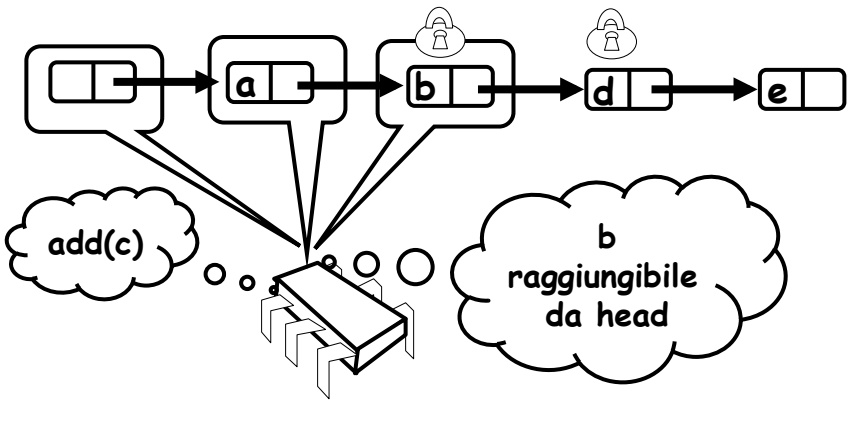


80

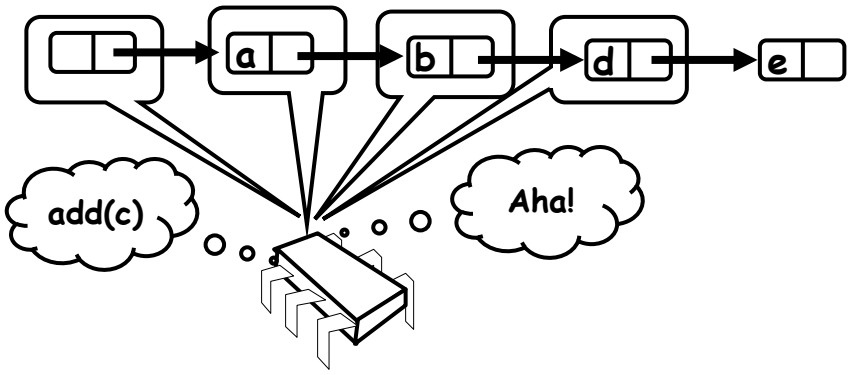
Cosa potrebbe andare storto?



81



Ancora problemi



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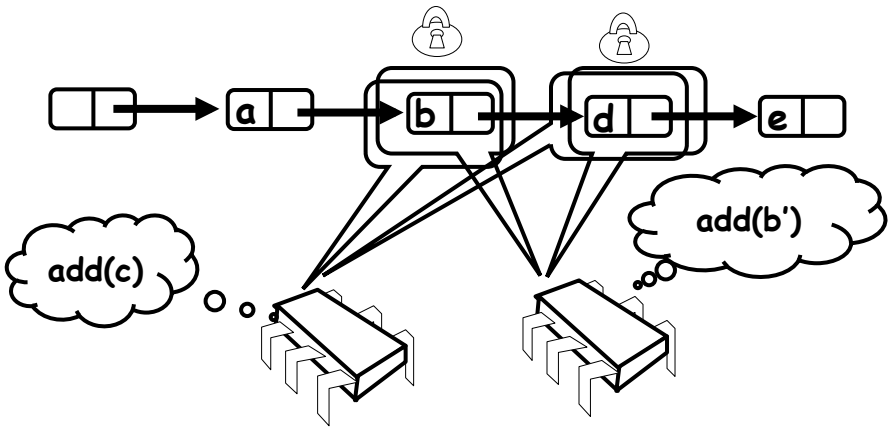
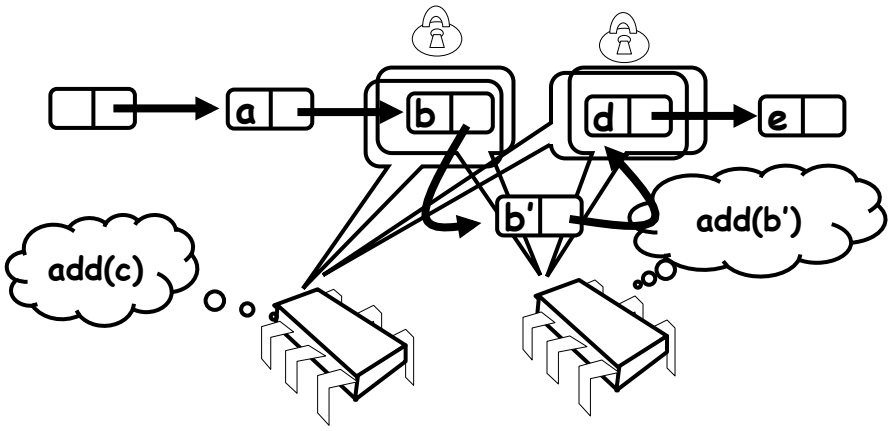
Ancora problemi



Ancora problemi



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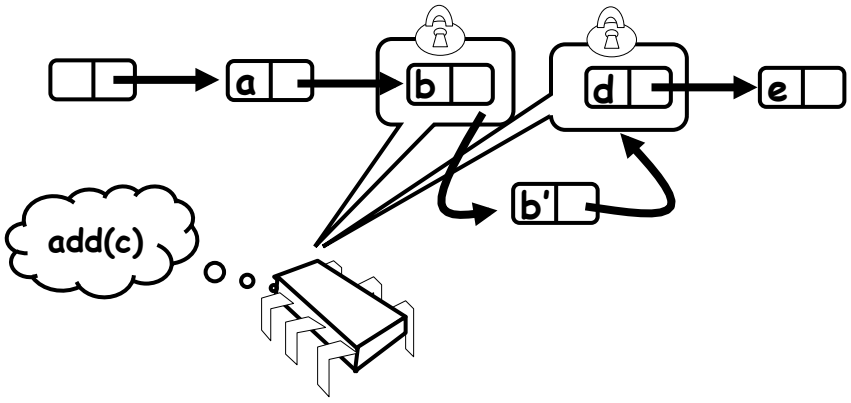
Ancora problemi



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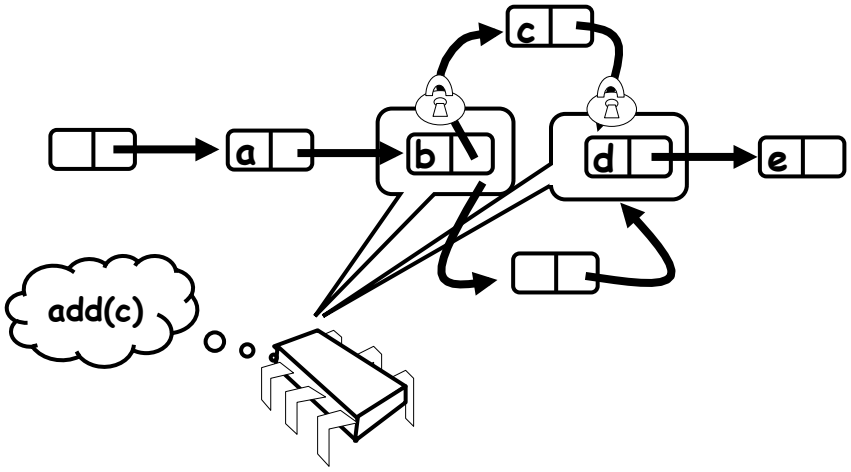
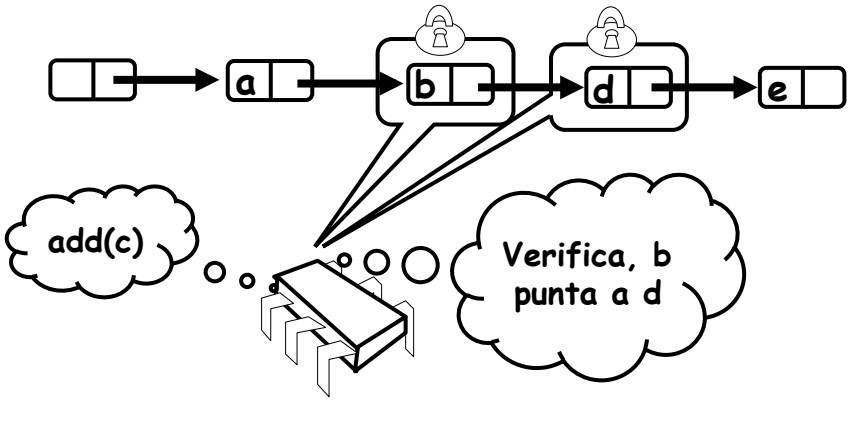
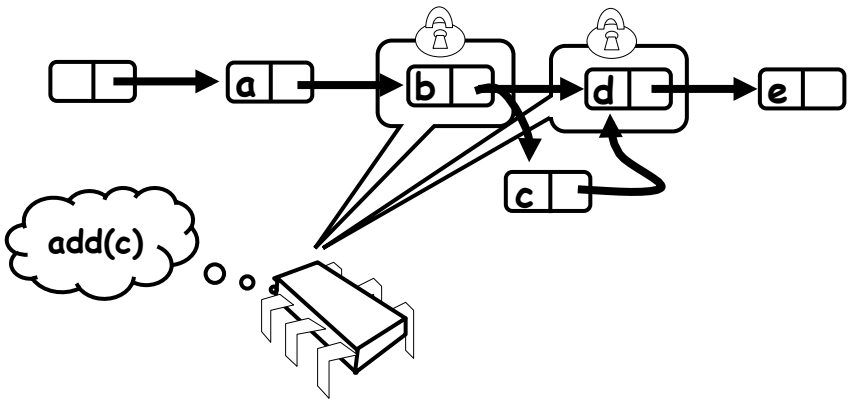
Ancora problemi



87



Punto di linearizzazione

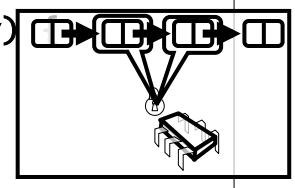


Verifica

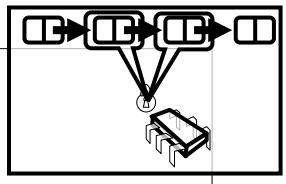
```
private boolean
 validate(Node pred,
          Node curr) {
 Node node = head;
 while (node.key <= pred.key) {
  if (node == pred)
   return pred.next == curr;
  node = node.next;
 }
 return false;
}
```

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

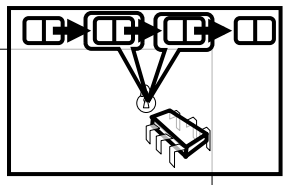
Predecessor & current



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

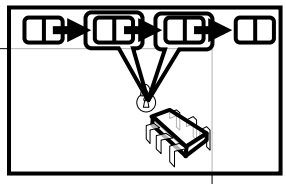


Inizializzazione



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

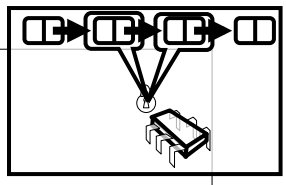
Ricerca



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

Raggiungibilita'

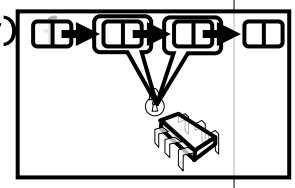
```
private boolean
 validate(Node pred,
          Node curr) {
 Node node = head;
 while (node.key <= pred.key) {
  if (node == pred)
   return pred.next == curr;
  node = node.next;
 }
 return false;
}
```



Check sulla continuazione

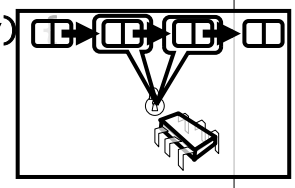
```
private boolean
 validate(Node pred,
          Node curr) {
 Node node = head;
 while (node.key <= pred.key) {
  if (node == pred)
   return pred.next == curr;
  node = node.next;
 }
 return false;
}
```

Scorrere in avanti



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

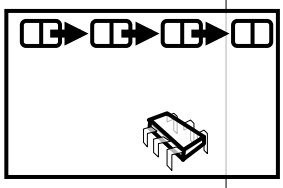
Predecessore non raggiungibile



Remove

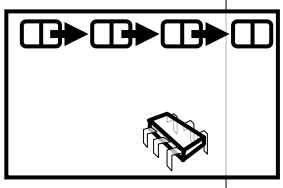
```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
      break;
    pred = curr;
    curr = curr.next;
   } …
```

```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```



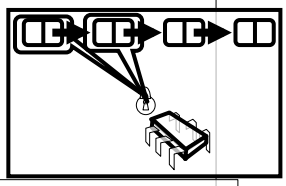
Search key

```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```



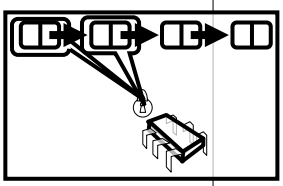
Retry: synchronization

```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```



Analisi predecessor & current

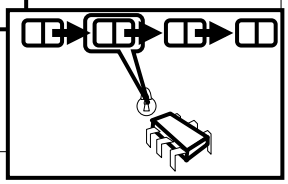
```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```



Guardia sulla chiave

```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```

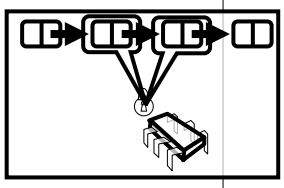
trovato



Remove: searching

```
public boolean remove(Item item) {
 int key = item.hashCode();
 retry: while (true) {
   Node pred = this.head;
   Node curr = pred.next;
   while (curr.key <= key) {
    if (item == curr.item)
     break;
    pred = curr;
    curr = curr.next;
   } …
```

Move along

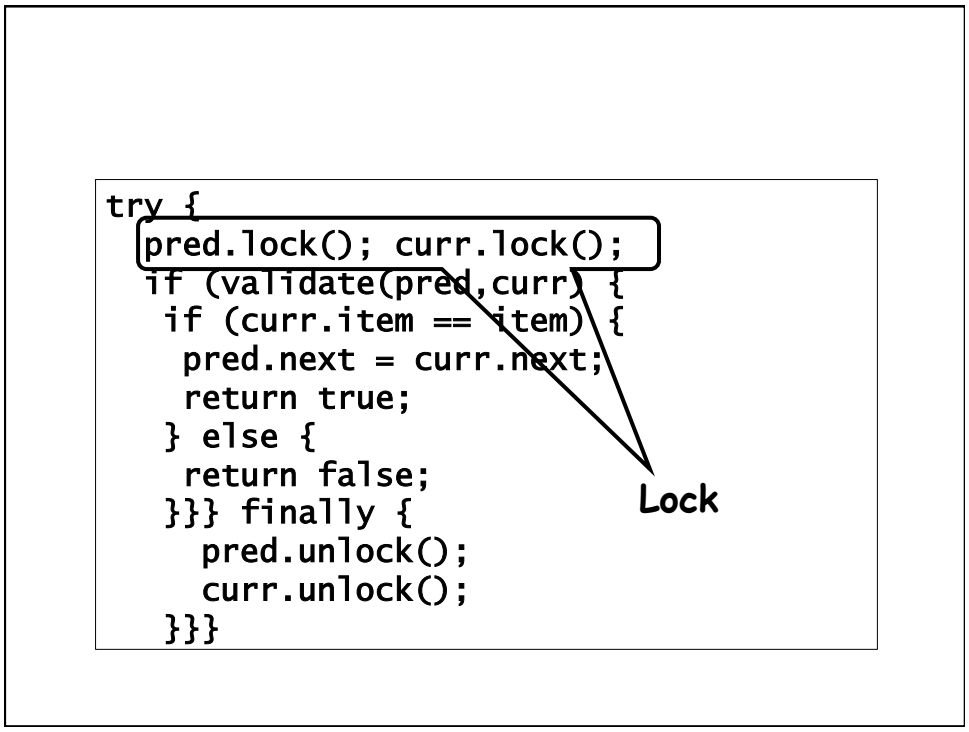


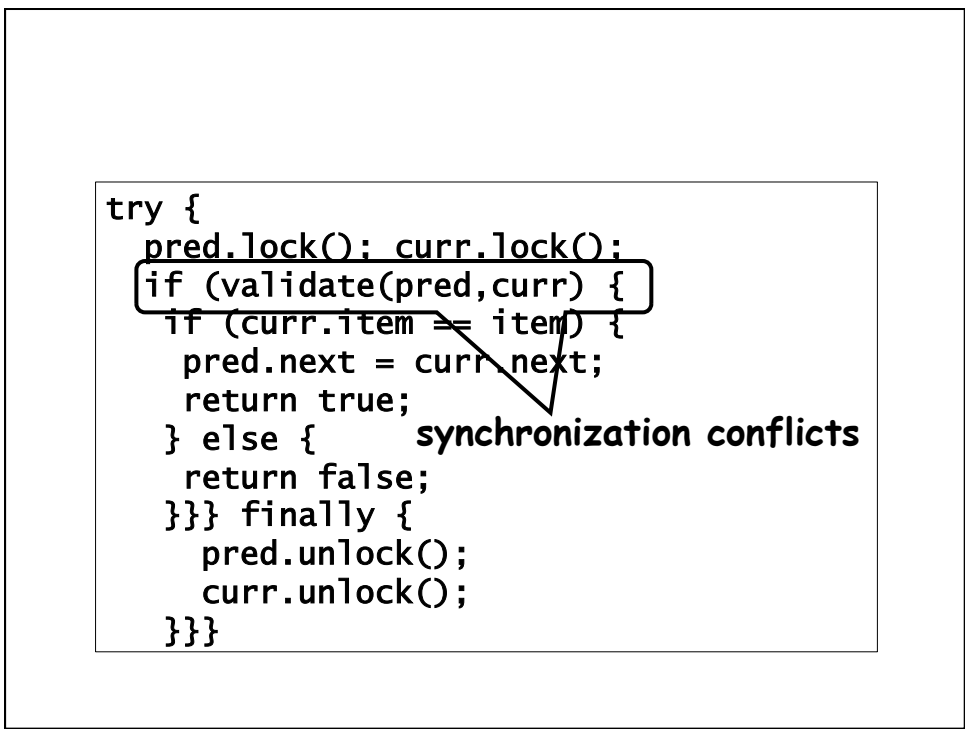
Remove Method

```
try {
  pred.lock(); curr.lock();
  if (validate(pred,curr) {
   if (curr.item == item) {
    pred.next = curr.next;
    return true;
   } else {
    return false;
   }}} finally {
     pred.unlock();
     curr.unlock();
   }}}
```

```
try {
  pred.lock(); curr.lock();
  if (validate(pred,curr) {
   if (curr.item == item) {
    pred.next = curr.next;
    return true;
   } else {
    return false;
   }}} finally {
     pred.unlock();
     curr.unlock();
   }}}
```

unlock


try {
pred.lock(); curr.lock();
if (validate(pred,curr) {
if (curr.item == item) {
pred.next = curr.next;
return true;
} else {
return false;
}}} finally {
pred.unlock();
curr.unlock();
}}}
Lock


try {
pred.lock(); curr.lock();
if (validate(pred,curr) {
if (curr.item == item) {
pred.next = curr.next;
return true;
} else {
return false;
}}} finally {
pred.unlock();
curr.unlock();
}}}
synchronization conflicts

```
try {
  pred.lock(); curr.lock();
  if (validate(pred,curr) {
   if (curr.item == item) {
    pred.next = curr.next;
    return true;
   } else {
    return false;
   }}} finally {
     pred.unlock();
     curr.unlock();
   }}}
```

trovato, rimozione

```
try {
  pred.lock(); curr.lock();
  if (validate(pred,curr) {
   if (curr.item == item) {
    pred.next = curr.next;
    return true;
   } else {
    return false;
   }}} finally {
     pred.unlock();
     curr.unlock();
   }}}
```

Non trovato

Valutazione

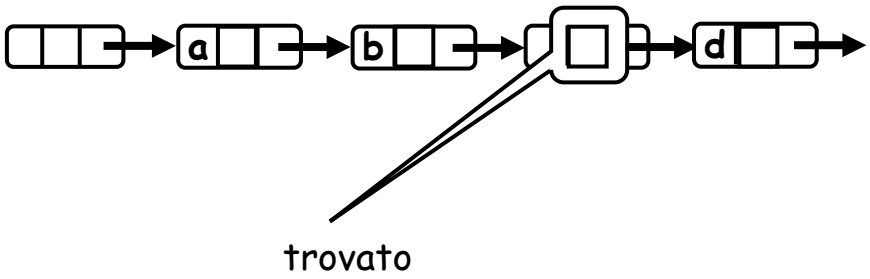
- Buona gestione dei lock
  - Performance
  - Concurrency
- Problemi
  - Scorrere la lista due volte
  - contains() comunque richiede lock

Lazy List

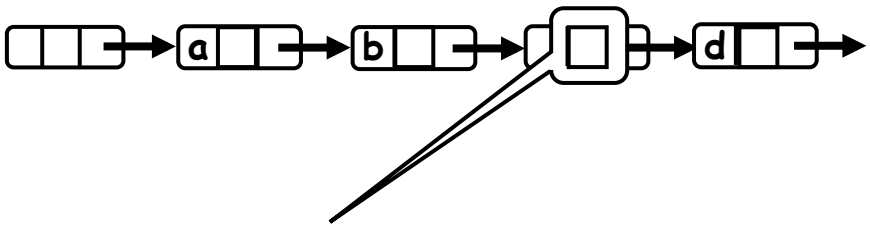
- remove()
  - Scasione della lista
  - Lock predecessor & current
- Logical delete
  - Marcare il nodo come eliminato (!!!!)
- Physical delete
  - Ridirezionare i puntatori

Lazy Removal

Lazy Removal



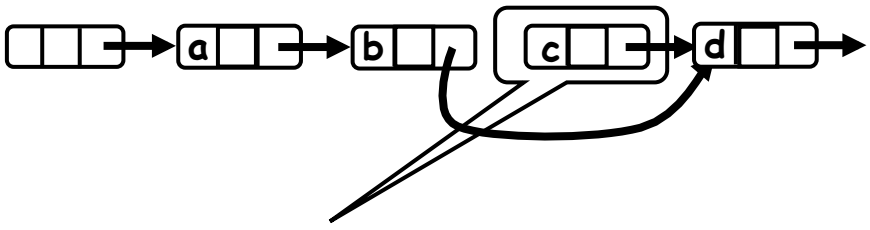
Lazy Removal



Logically deleted

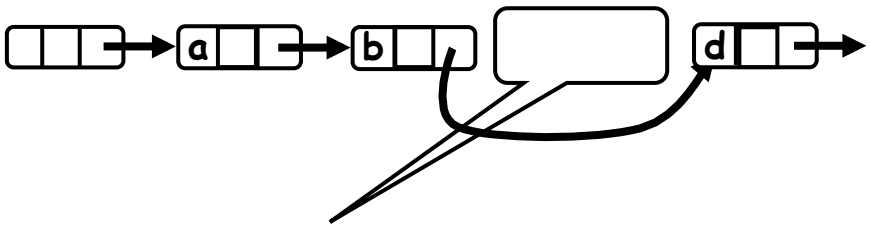
115

Lazy Removal

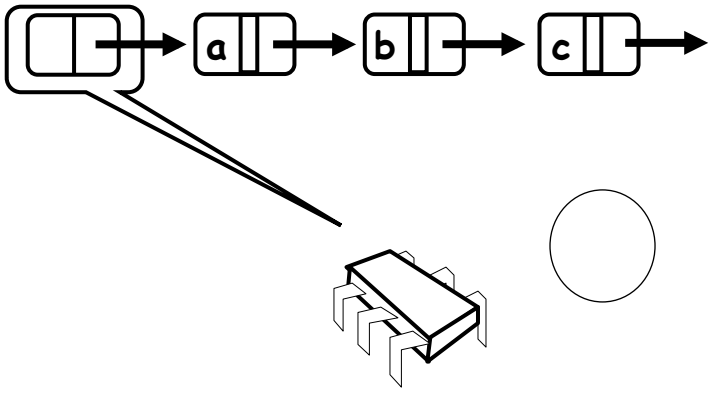


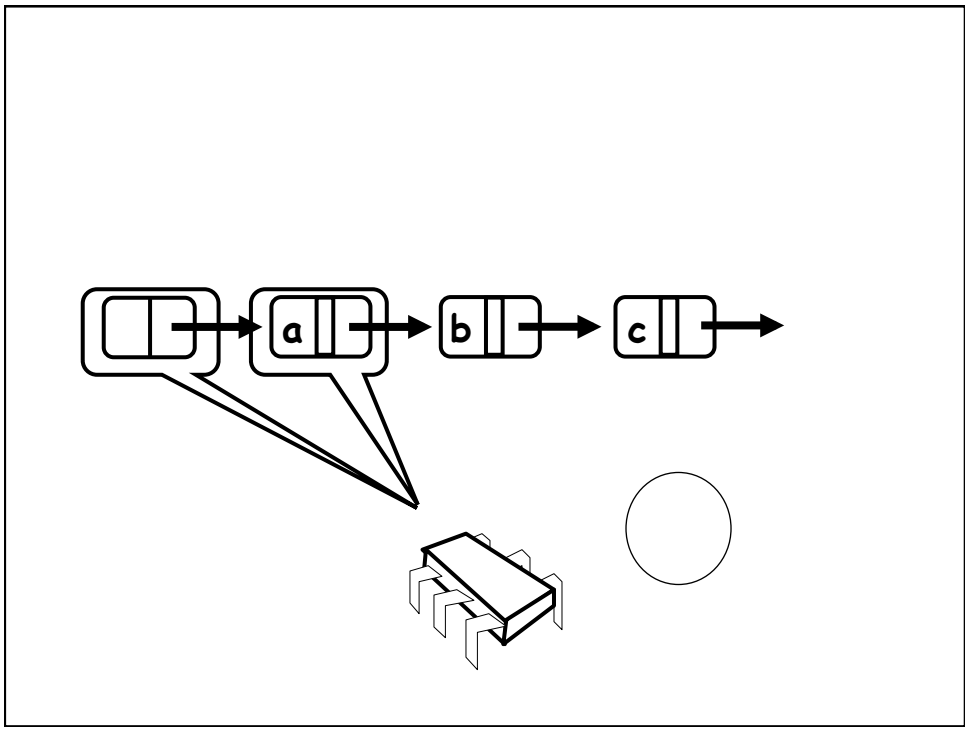
Physically deleted

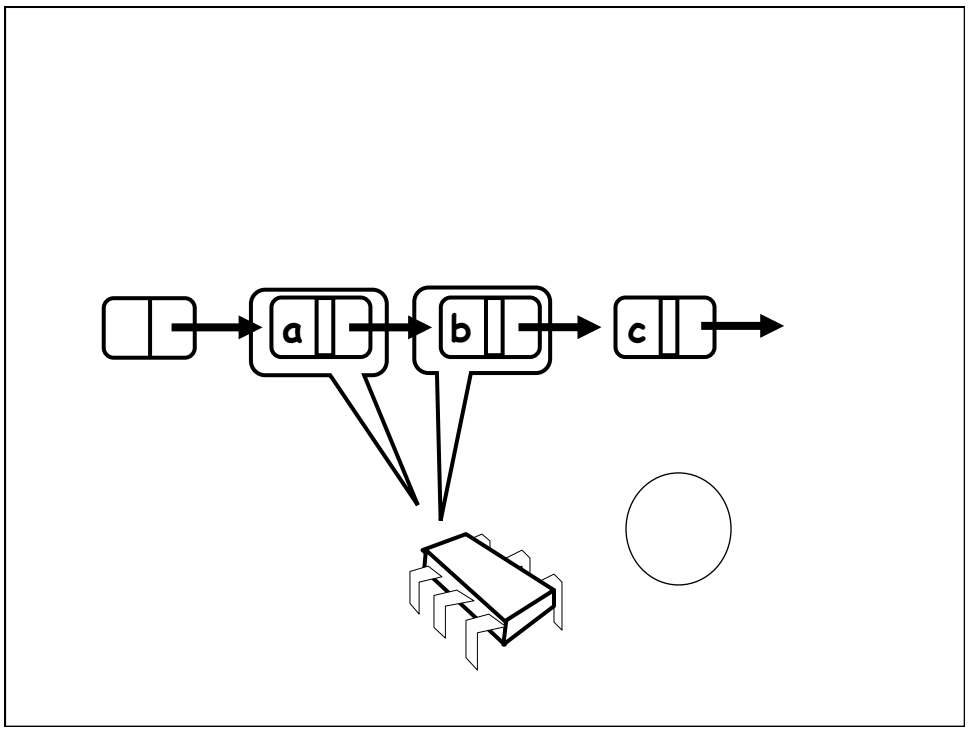
Lazy Removal

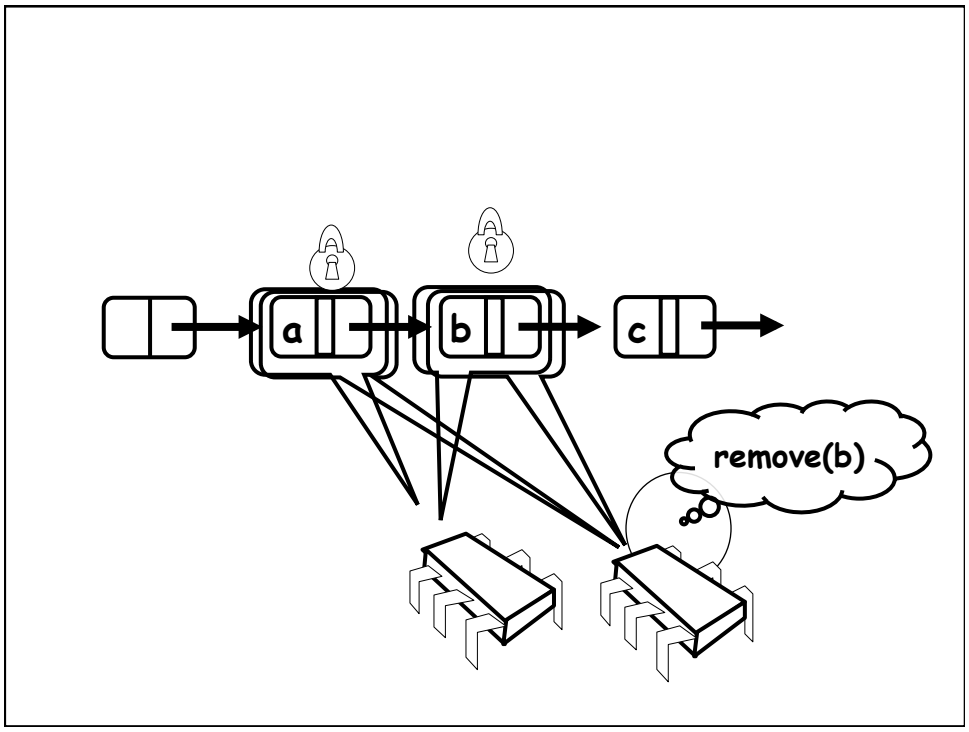


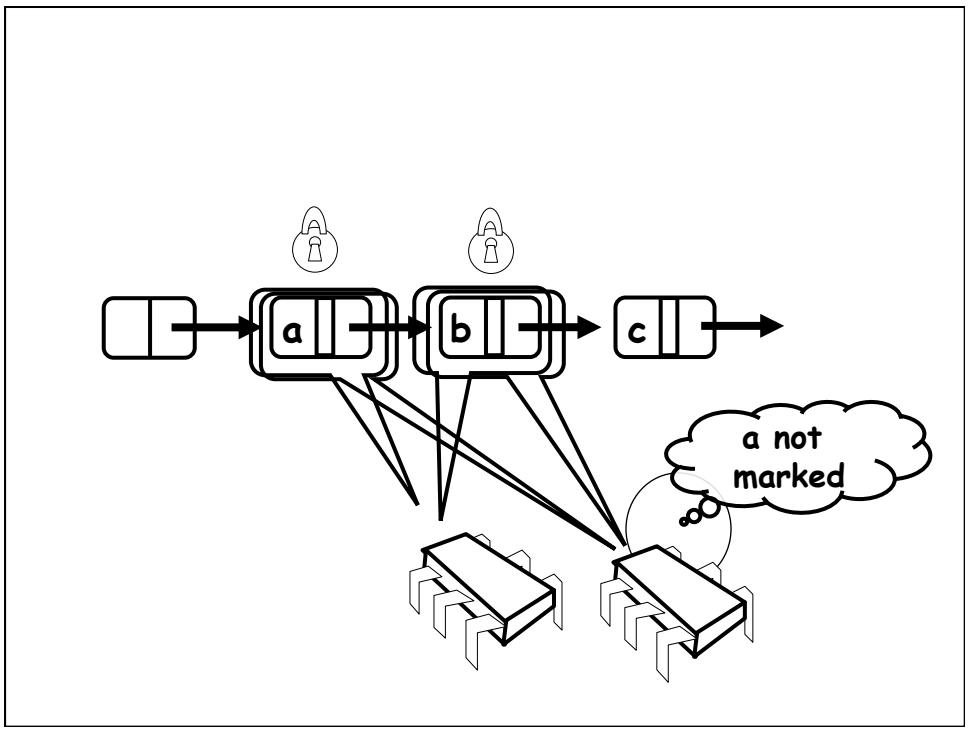
Physically deleted

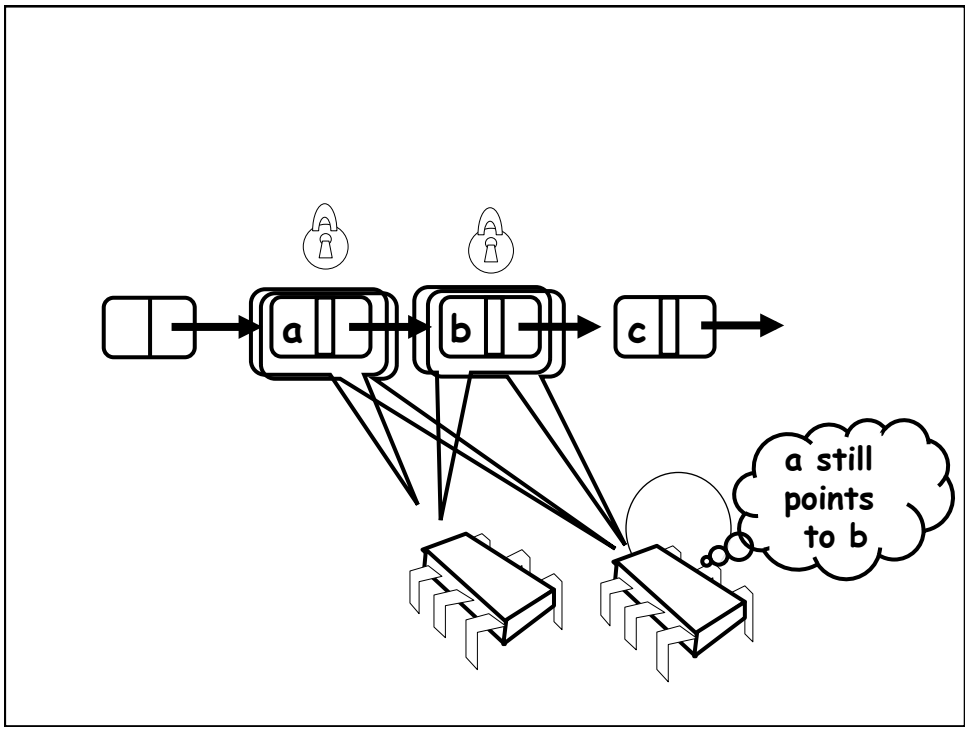


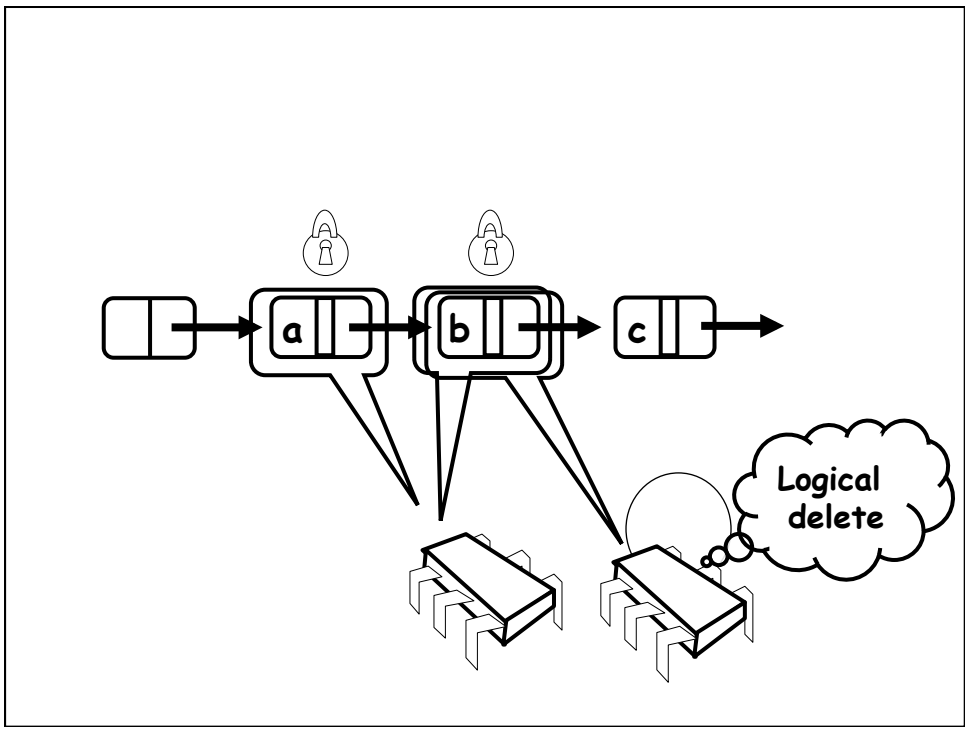

a
b
c

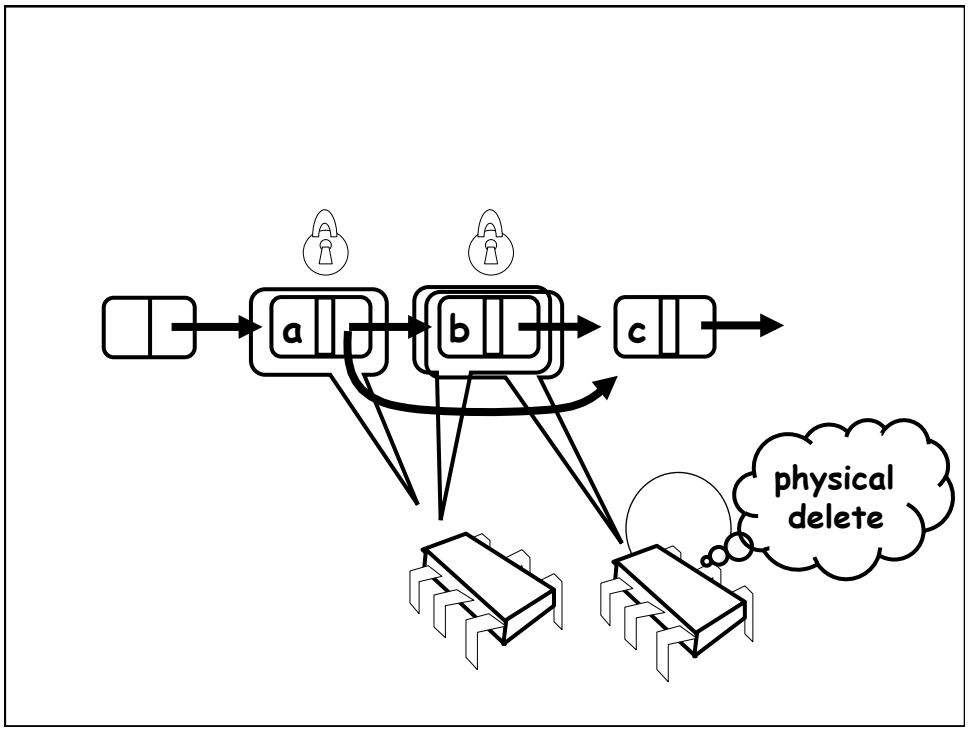

a
b
c

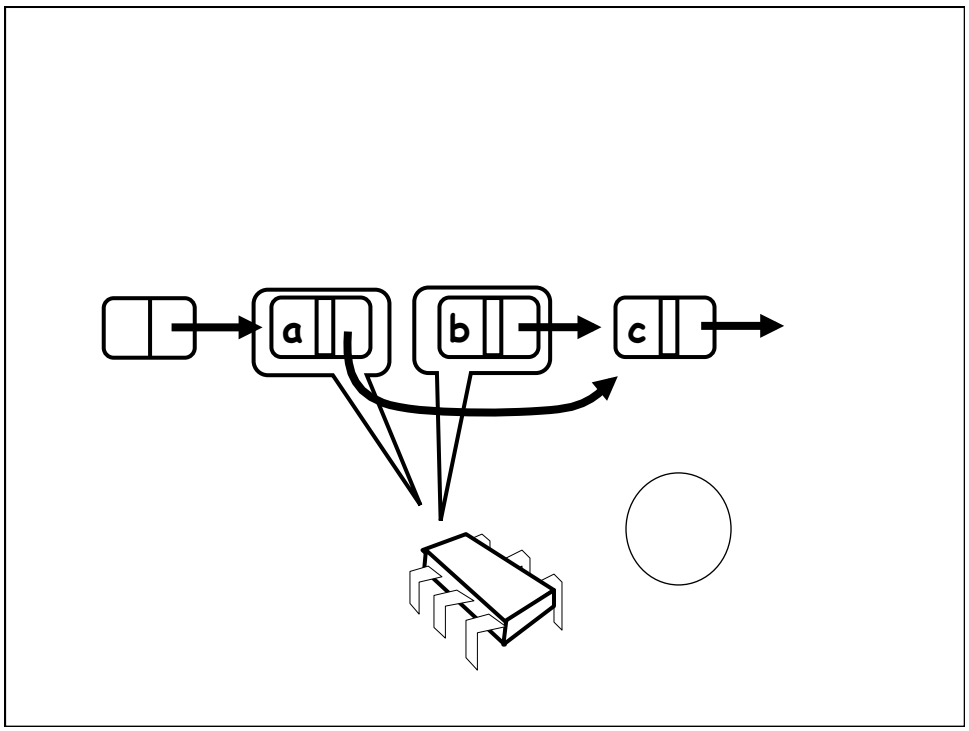

a
b
c
remove(b)


a
b
c
a not
marked


a
b
c
a still
points
to b


a
b
c
Logical
delete

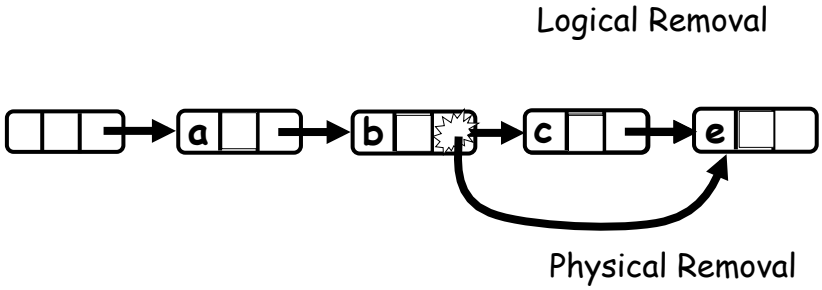

a
b
c
physical
delete


a
b
c

Abstraction Function

- alpha(head) =
  - { x | esiste a tale che
    - a raggiungibile da head e
    - a.item = x e
    - a non marcato
  - }

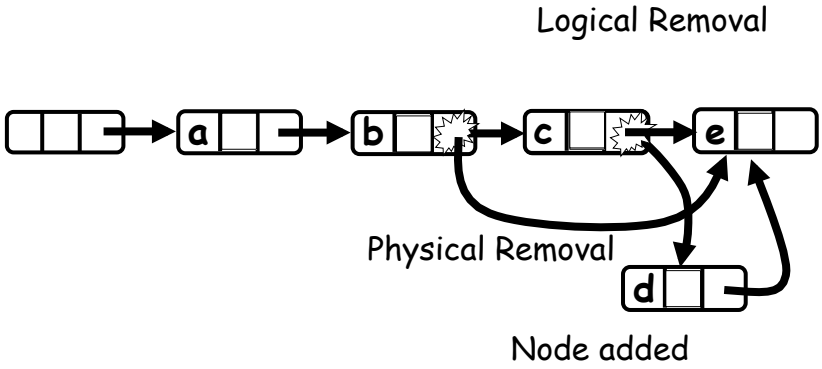
Lock-free Lists



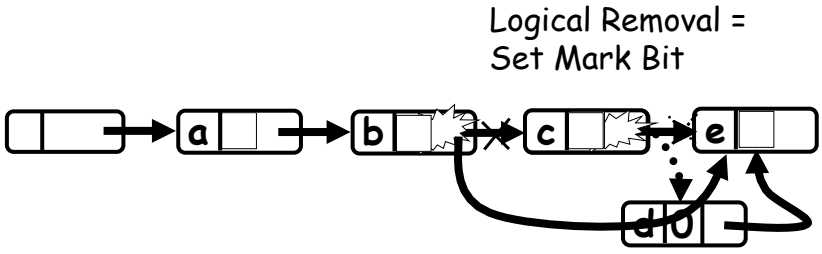
Non basta

128

Problema



Bit di marcatura e puntatori



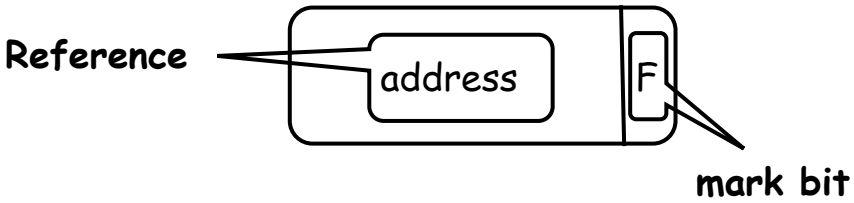
AtomicMarkableReference

AtomicMarkableReference

- Operazione atomica
  - Modificare il puntatore
  - Modificare la marcatura
- Remove (due passi)
  - Operare sul mark bit del campo next
  - Modificare il predecessor

In Java

- AtomicMarkableReference class
  - Java.util.concurrent.atomic package

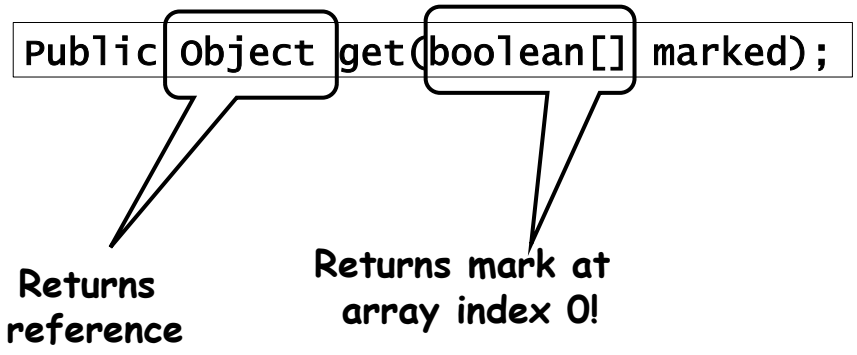


Extracting Reference & Mark

```
Public Object get(boolean[] marked);
```

Extracting Reference & Mark

```
Public Object get(boolean[] marked);
```



"To Lock or Not to Lock"

- Locking vs. Non-blocking: visioni estreme
- La risposta: combinare blocking e non blocking
  - Esempi: Lazy list :blocking add() e remove() con wait-free contains()