

Múltiplas Variáveis de Condição

Sistemas Distribuídos

Armazém

```
class Warehouse {  
    private Lock l = new ReentrantLock();  
    private Map<String, Item> stock = new HashMap<>();  
  
    private class Item {  
        int q = 0;  
        Condition isEmpty = l.newCondition();  
    }  
  
    public void supply (String item, int quantity);  
    public void consume (String[] items)  
        throws InterruptedException;  
}
```

Armazém

- Método Warehouse.supply

```
void supply (String item, int quantity) {  
    Item it = this.get(item);  
    it.q += quantity;  
}
```

- Método Warehouse.consume

```
void consume (String[] items) throws InterruptedException {  
    for (String item : items) {  
        Item it = this.get(item);  
        it.q -= 1;  
    }  
}
```

Armazém

- Cliente Greedy
 - Método Warehouse.supply

```
public void supply (String item, int quantity) {  
    l.lock();  
    Item it = get(item);  
    it.q += quantity;  
    it.isEmpty.signalAll();  
    l.unlock();  
}
```

Armazém

- Cliente Greedy
 - Método Warehouse.supply

```
public void supply (String item, int quantity) {  
    l.lock();  
    Item it = get(item);  
    it.q += quantity;  
    it.isEmpty.signalAll();  
    l.unlock();  
}
```

supply_

Armazém

- Cliente Greedy
 - Método Warehouse.consume

```
void consume (String[] items) throws InterruptedException {  
    l.lock();  
    for (String item : items) {  
        Item it = this.get(item);  
        while (it.q == 0) {  
            it.isEmpty.await();  
        }  
        it.q -= 1;  
    }  
    l.unlock();  
}
```

Armazém

- Cliente Greedy
 - Método Warehouse.consume

```
void consume (String[] items) throws InterruptedException {  
    l.lock();  
    for (String item : items) {  
        Item it = this.get(item);  
        while (it.q == 0) {  
            it.isEmpty.await();  
        }  
        it.q -= 1;  
    }  
    l.unlock();  
}
```

consume_

Abstração do operador
consumir, para um único item.

● Cliente **Greedy**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3', 5);  
  l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Lock:	<i>em espera p/ lock:</i>
Wait-Set:	

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5



Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T₁

em espera p/ lock: T₂,T₃

Wait-Set:

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5



Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

Cliente 1 {
 l.lock();
 consume_('item2');
 consume_('item3');
 consume_('item4');
 l.unlock();
}

...
while(item.q == 0)
 item.isEmpty.await();
 item.q -= 1;
 ...
l.unlock();
}

T₃

Cliente 3 {
 l.lock();
 supply_('item3',5);
 l.unlock();
}

Cliente 3 {
 l.lock();
 supply_('item2',5);
 l.unlock();
}

Lock: T₁ **em espera p/ lock:** T₂,T₃

Wait-Set:

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5

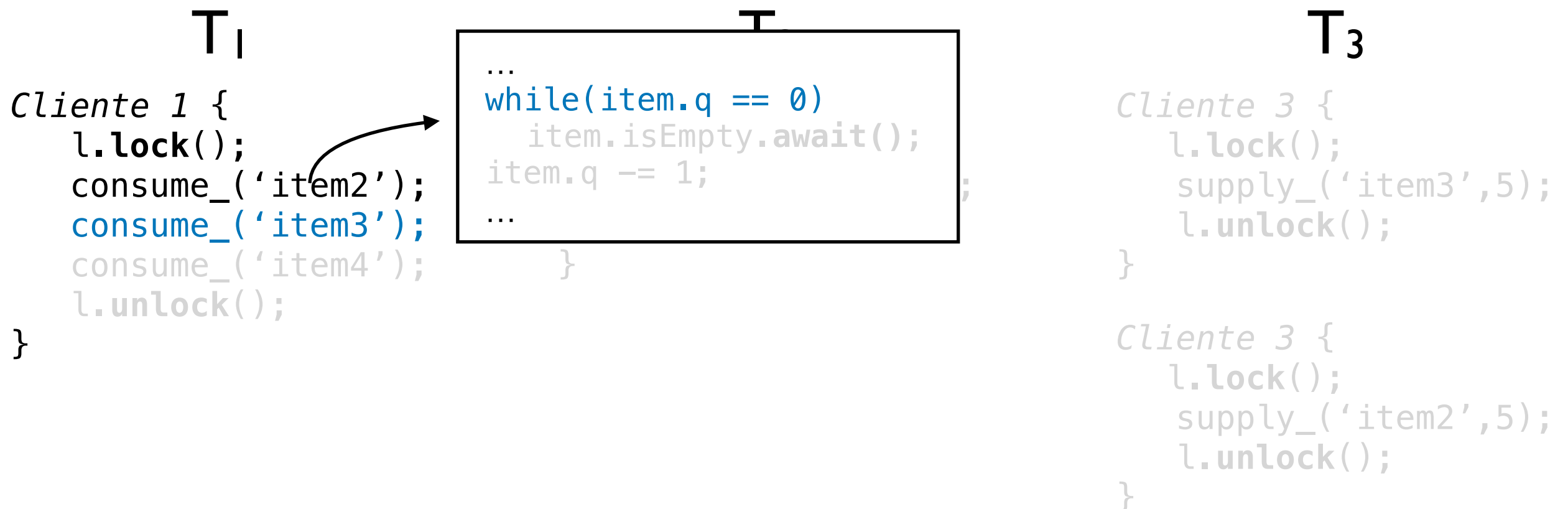
● Cliente **Greedy**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T ₁	em espera p/ lock: T ₂ , T ₃
Wait-Set:	

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5

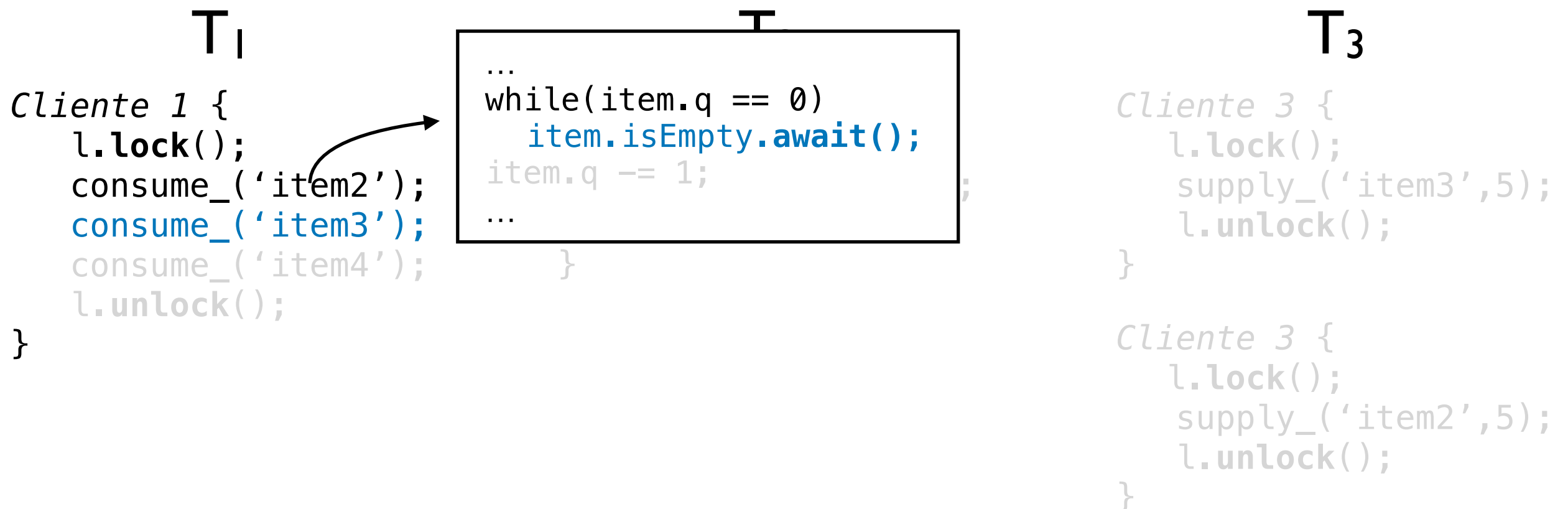
● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock:	em espera p/ lock: T2,T3
Wait-Set:	T1(item3)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5

● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

```
...  
while(item.q == 0)  
  item.isEmpty.await();  
item.q -= 1;  
...  
l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T₂ **em espera p/ lock:** T₃

Wait-Set: T₁(item3)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5

● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

```
...  
while(item.q == 0)  
  item.isEmpty.await();  
item.q -= 1;  
...  
l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: em espera p/ lock: T3

Wait-Set: T1(item3), T2(item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5



● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3', 5);  
  l.unlock();  
}
```

```
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Embora o Cliente 1 esteja à espera do 'item3', este já consumiu o 'item2'. Desta forma, o Cliente 2 ficará bloqueado até ao reabastecimento do 'item2'.

Lock: em espera p/ lock: T_3

Wait-Set: T_1 (item3), T_2 (item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5

● Cliente **Greedy**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T_3 **em espera p/ lock:**

Wait-Set: T_1 (item3), T_2 (item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	0	5



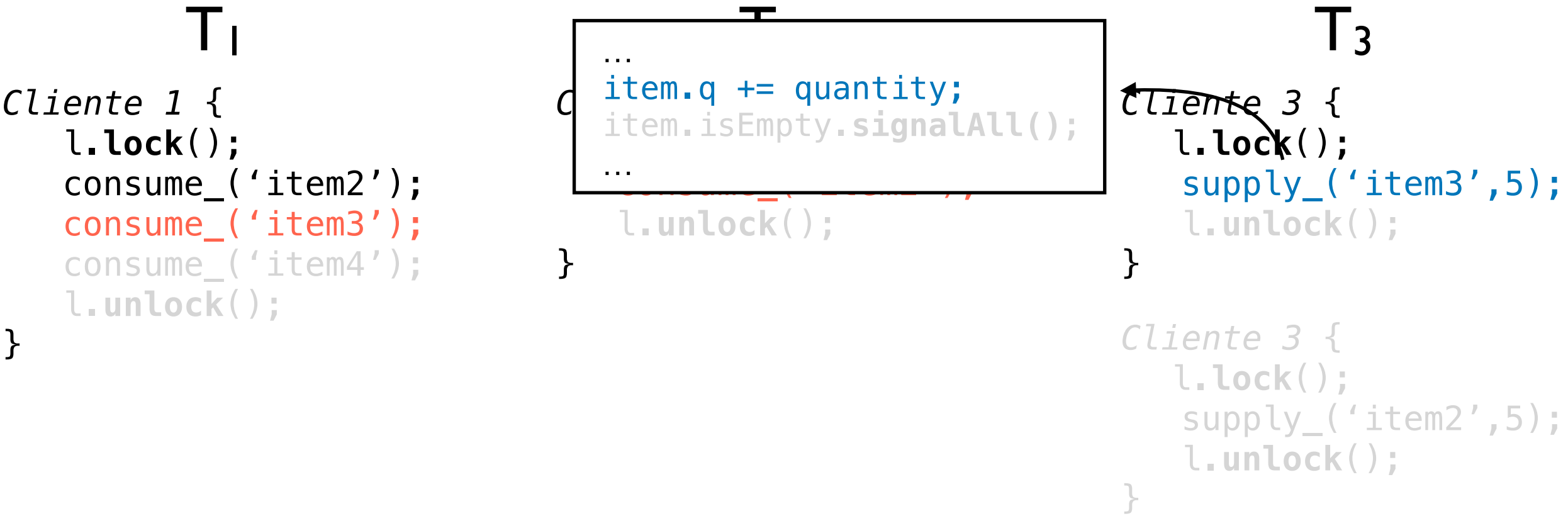
Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T3 **em espera p/ lock:**

Wait-Set: T1(item3),T2(item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	5	5



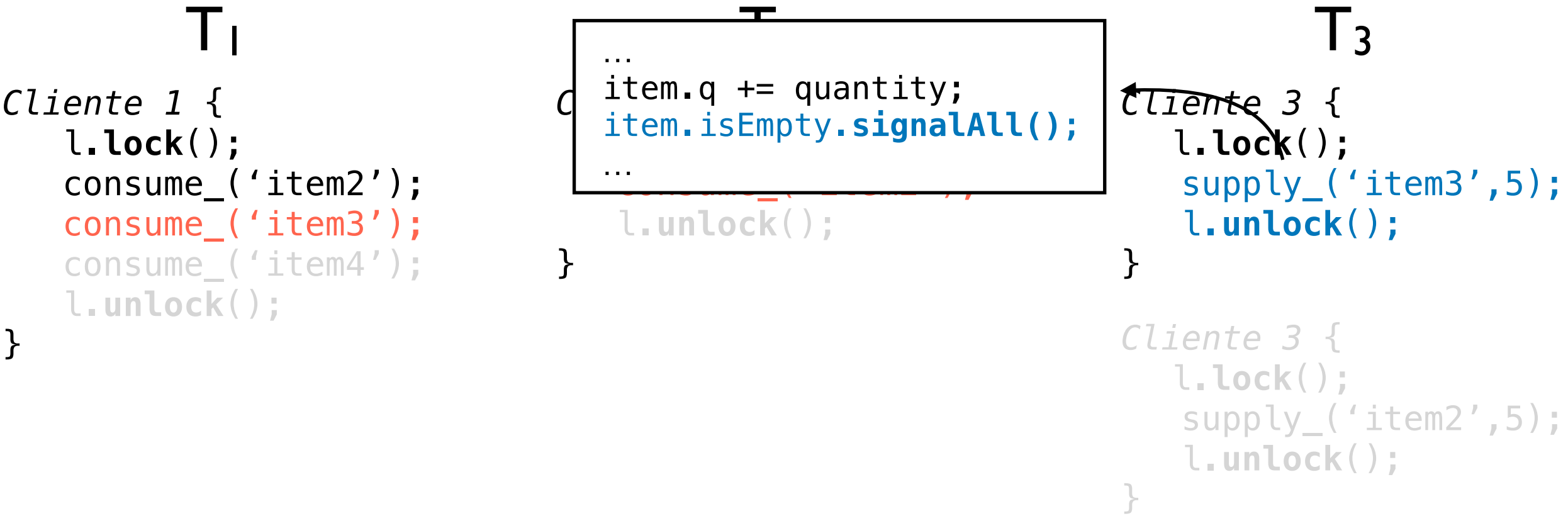
Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T3

em espera p/ lock:

Wait-Set: T1(item3),T2(item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	5	5

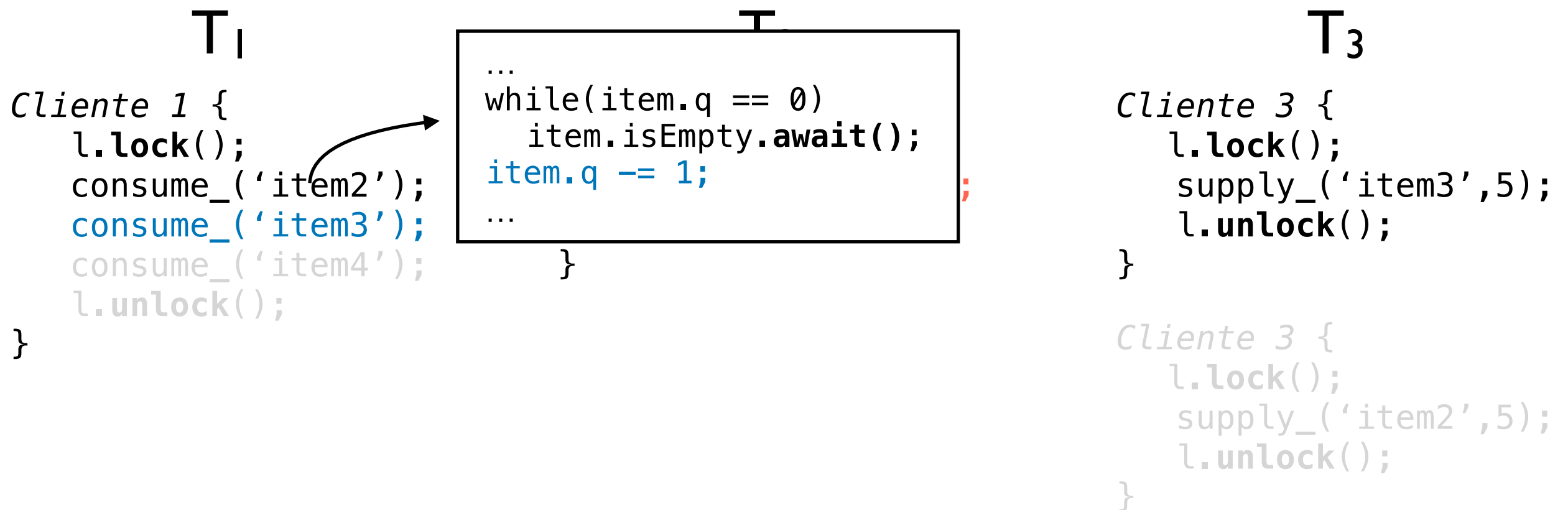
● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T₁ **em espera p/ lock:** T₃

Wait-Set: T₂(item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	4	5

● Cliente **Greedy**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3', 5);  
  l.unlock();  
}  
  
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Lock: T_1 *em espera p/ lock:* T_3

Wait-Set: $T_2(\text{item2})$

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	4	4

● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}
```

```
...  
item.q += quantity;  
item.isEmpty.signalAll();  
...
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3', 5);  
  l.unlock();  
}
```

```
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Lock: T_3 **em espera p/ lock:**

Wait-Set: $T_2(\text{item2})$

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	4	4

● Cliente Greedy

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```
Cliente 1 {  
  l.lock();  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T_2

```
Cliente 2 {  
  l.lock();  
  consume_('item2');  
  l.unlock();  
}  
...  
item.q += quantity;  
item.isEmpty.signalAll();  
...
```

T_3

```
Cliente 3 {  
  l.lock();  
  supply_('item3', 5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Lock: T3 **em espera p/ lock:**

Wait-Set: T2(item2)

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	4	4

Cliente **Greedy**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T_1

```

Cliente 1 {
    l.lock();
    consume_('item2');
    consume_('item3');
    consume_('item4');
    l.unlock();
}
    
```

T_2

```

Cliente 2 {
    l.lock();
    consume_('item2');
    l.unlock();
}
    
```

```

...
while(item.q == 0)
    item.isEmpty.await();
item.q -= 1;
...
l.unlock();
    
```

```

Cliente 3 {
    l.lock();
    supply_('item2',5);
    l.unlock();
}
    
```

Lock: T_2 *em espera p/ lock:*

Wait-Set:

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	4	4	4

Armazém

- Cliente Cooperativo
 - Método Warehouse.consume

```
void consume (String[] items) throws InterruptedException {  
    l.lock();  
    int i = 0;  
    while (i < items.length) {  
        Item it = this.get(items[i]);  
        i++;  
        while (it.q == 0) {  
            it.isEmpty.await();  
            i = 0;  
        }  
    }  
    for (String item : items) {  
        this.get(item).q -= 1;  
    }  
    l.unlock();  
}
```


Armazém

- Cliente Cooperativo
 - Método Warehouse.consume

```
void consume (String[] items) throws InterruptedException {  
    l.lock();  
    int i = 0;  
    while (i < items.length) {  
        Item it = this.get(items[i]);  
        i++;  
        while (it.q == 0) {  
            it.isEmpty.await();  
            i = 0;  
        }  
    }  
    for (String item : items) {  
        this.get(item).q -= 1;  
    }  
    l.unlock();  
}
```

preconsume_

Operador que regista a intenção de consumir um item.

consume_

Abstração do operador consumir, para um único item.

● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock:	em espera p/ lock:
Wait-Set:	registro:

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T ₁	em espera p/ lock: T ₂ ,T ₃
Wait-Set:	registro: T ₁ = 0

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

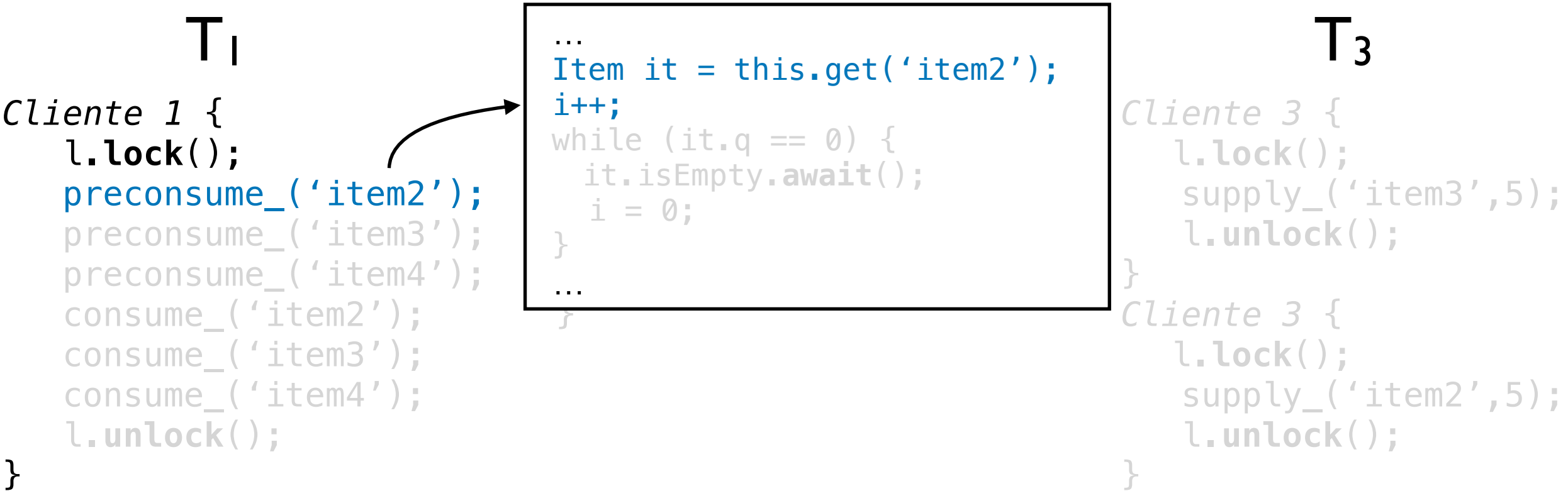
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



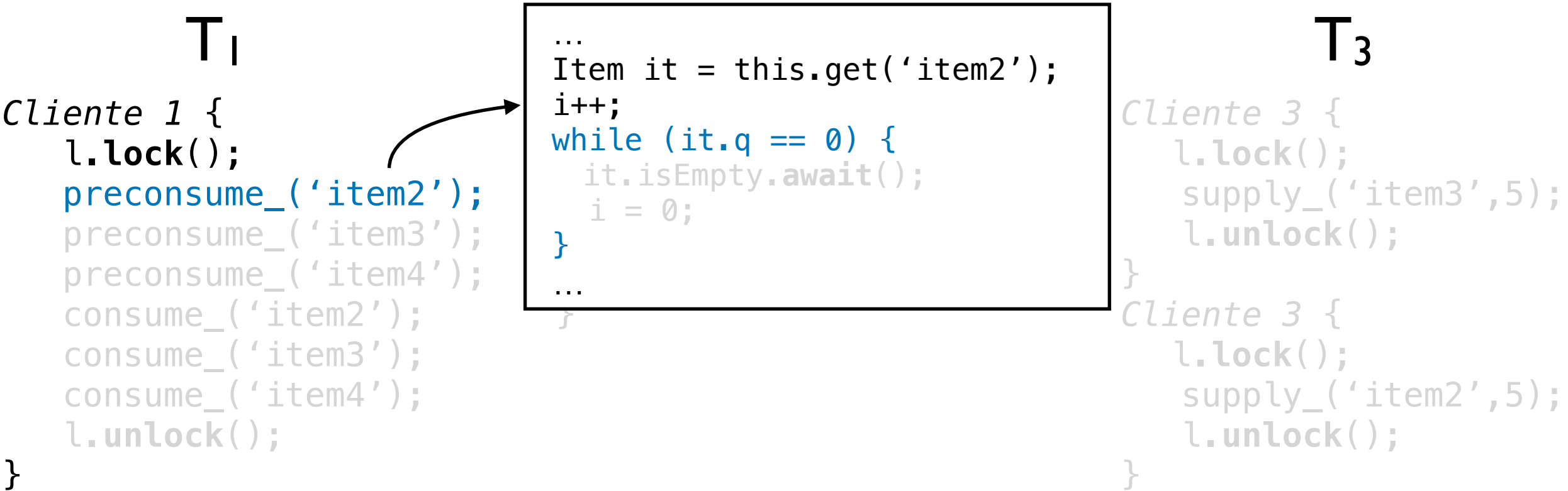
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T1	em espera p/ lock: T2,T3
Wait-Set:	registro: T1 = 1

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

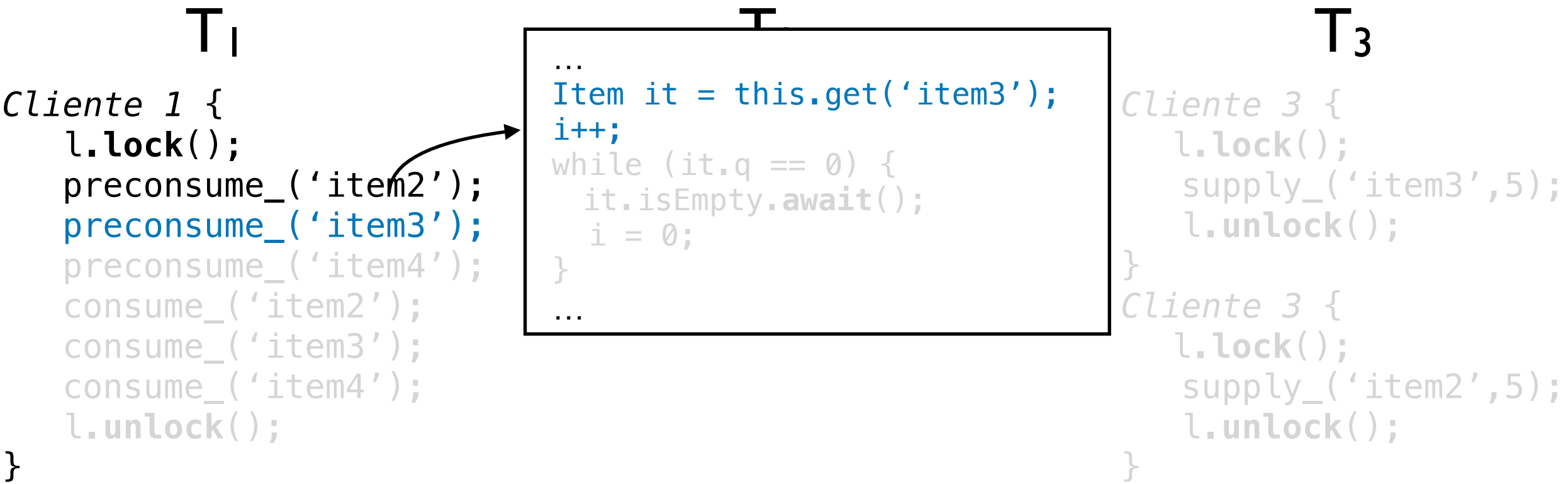
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T ₁	em espera p/ lock: T ₂ ,T ₃
Wait-Set:	registro: T ₁ = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

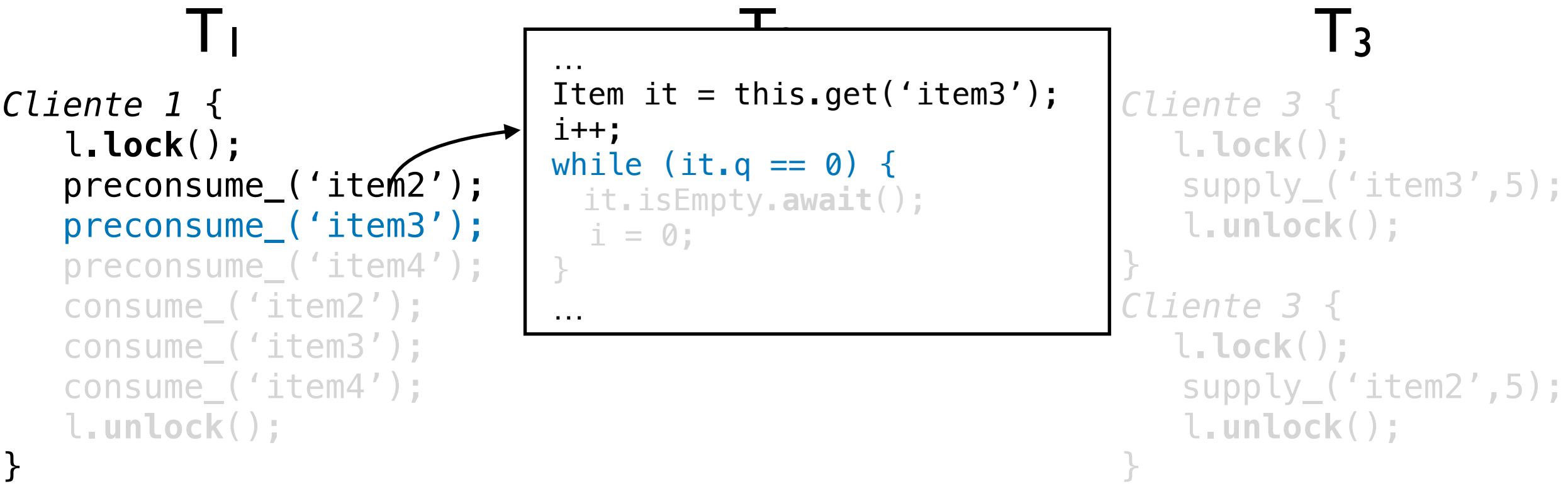
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T1	em espera p/ lock: T2,T3
Wait-Set:	registro: T1 = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

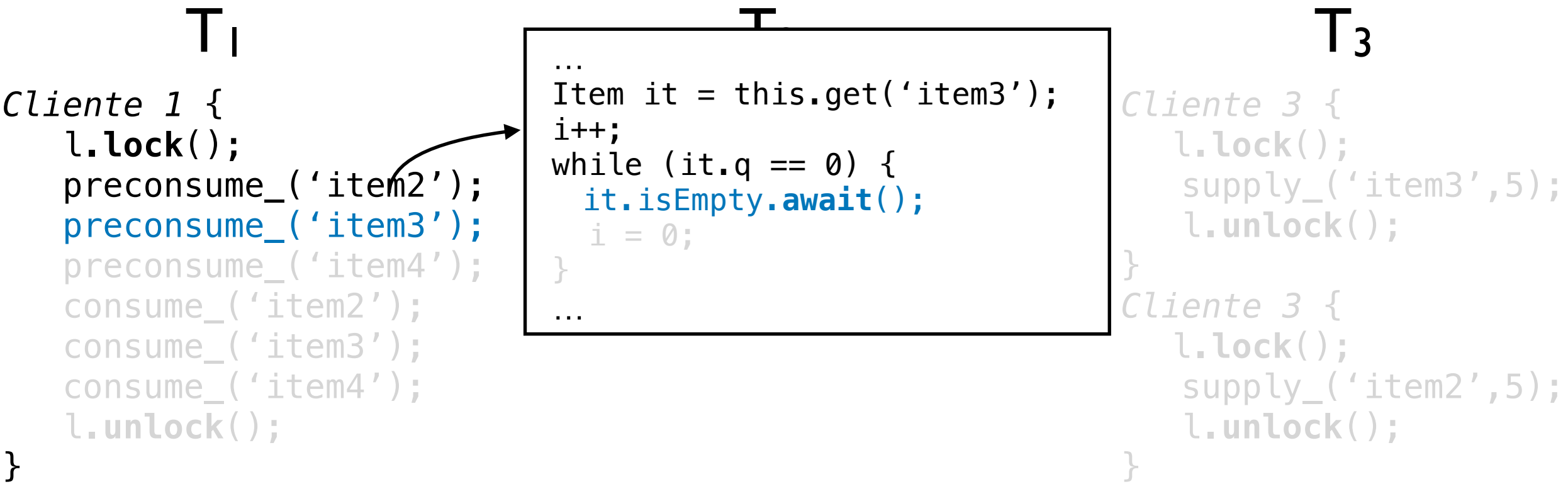
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: em espera p/ lock: T2,T3

Wait-Set: T1(item3) **registro:** T1 = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

```
...  
Item it = this.get('item2');  
i++;  
while (it.q == 0) {  
  it.isEmpty.await();  
  i = 0;  
}  
...
```

```
Cliente 3 {  
  l.lock();  
  supply_('item2', 5);  
  l.unlock();  
}
```

Lock: T₂ **em espera p/ lock:** T₃

Wait-Set: T₁(item3) **registro:** T₁ = 2; T₂ = 1

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

● Cliente **Cooperativo**

- Cliente 1:** consume (['item2', 'item3', 'item4'])
- Cliente 2:** consume (['item2'])
- Cliente 3:** supply ('item3', 5)
- Cliente 3:** supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

```
...  
Item it = this.get('item2');  
i++;  
while (it.q == 0) {  
  it.isEmpty.await();  
  i = 0;  
}  
...
```

```
...  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

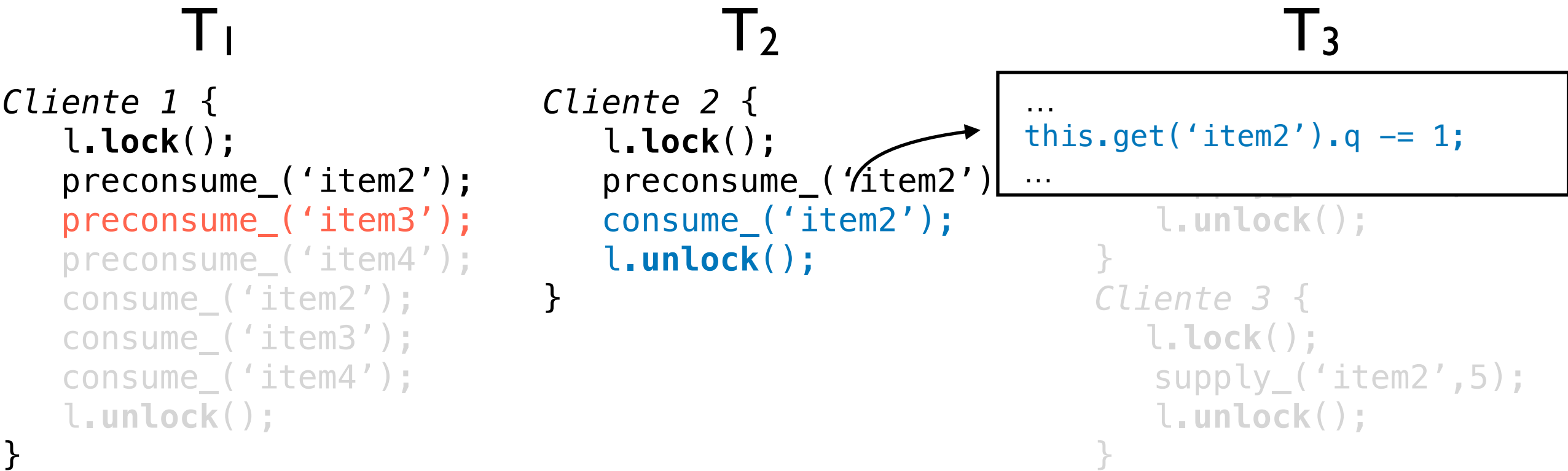
Lock: T2 **em espera p/ lock:** T3

Wait-Set: T1(item3) **registro:** T1 = 2; T2 = 1

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	1	0	5

● Cliente **Cooperativo**

- Cliente 1:** consume (['item2', 'item3', 'item4'])
- Cliente 2:** consume (['item2'])
- Cliente 3:** supply ('item3', 5)
- Cliente 3:** supply ('item2', 5)



● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {
  l.lock();
  preconsume_('item2');
  preconsume_('item3');
  preconsume_('item4');
  consume_('item2');
  consume_('item3');
  consume_('item4');
  l.unlock();
}
```

T

```
...
item.q += quantity;
item.isEmpty.signalAll();
...
consume_('item2');
l.unlock();
}
```

T₃

```
Cliente 3 {
  l.lock();
  supply_('item3',5);
  l.unlock();
}
Cliente 3 {
  l.lock();
  supply_('item2',5);
  l.unlock();
}
```

Lock: T₃ **em espera p/ lock:** T₁

Wait-Set: **registro:** T₁ = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	0	5	5

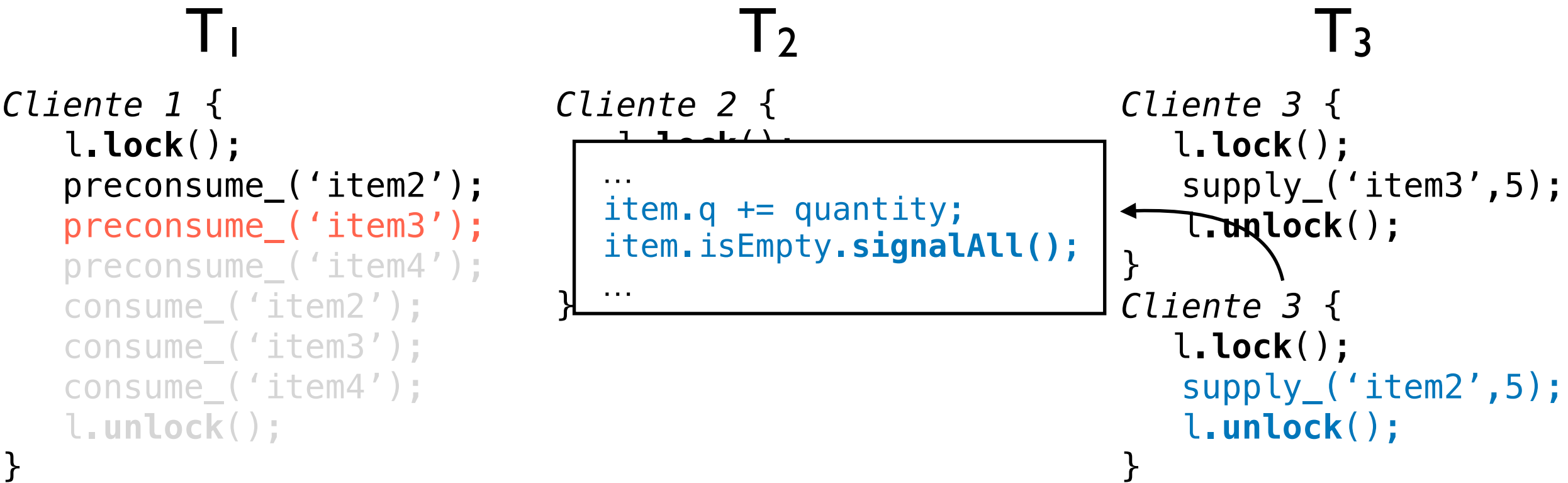
● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)



Lock: T3 **em espera p/ lock:**

Wait-Set: T1(item3) **registro:** T1 = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	5	5



Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
    l.lock();  
    preconsume_('item2');  
    preconsume_('item3');  
    preconsume_('item4');  
    consume_('item2');  
    consume_('item3');  
    consume_('item4');  
    l.unlock();  
}
```

```
...
Item it = this.get('item3');
i++;
while (it.q == 0) {
    it.isEmpty.await();
    i = 0;
}
...
```

T₃

```
Cliente 3 {  
    l.lock();  
    supply_('item3',5);  
    l.unlock();  
}  
  
Cliente 3 {  
    l.lock();  
    supply_('item2',5);  
    l.unlock();  
}
```

Lock: **TI** *em espera p/ lock:*
Wait-Set: **registro:** **TI = 0**

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	5	5

● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T ₁	em espera p/ lock:
Wait-Set:	registro: T ₁ = 1

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	5	5

● Cliente **Cooperativo**

- Cliente 1:** consume (['item2', 'item3', 'item4'])
- Cliente 2:** consume (['item2'])
- Cliente 3:** supply ('item3', 5)
- Cliente 3:** supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T1	em espera p/ lock:
Wait-Set:	registro: T1 = 2

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	5	5



● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  consume_('item2');  
  l.unlock();  
}
```

T₃

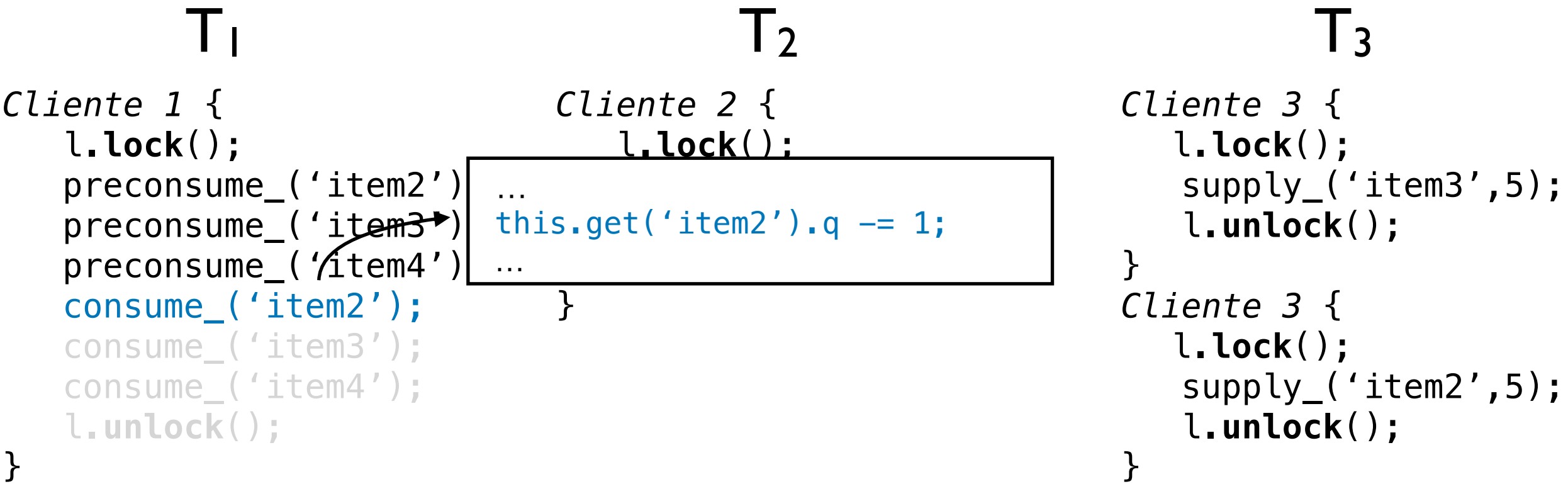
```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T ₁	em espera p/ lock:
Wait-Set:	registro: T ₁ = 3

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	5	5	5

● Cliente **Cooperativo**

- Cliente 1:** consume (['item2', 'item3', 'item4'])
- Cliente 2:** consume (['item2'])
- Cliente 3:** supply (item3, 5)
- Cliente 3:** supply (item2, 5)



Lock: T1	em espera p/ lock:
Wait-Set:	registro: T1 = 3

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	4	5	5



● Cliente **Cooperativo**

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```
Cliente 1 {  
  l.lock();  
  preconsume_('item2');  
  preconsume_('item3');  
  preconsume_('item4');  
  consume_('item2');  
  consume_('item3');  
  consume_('item4');  
  l.unlock();  
}
```

T₂

```
Cliente 2 {  
  l.lock();  
  preconsume_('item2');  
  ...  
  this.get('item3').q -= 1;  
  ...  
}
```

T₃

```
Cliente 3 {  
  l.lock();  
  supply_('item3',5);  
  l.unlock();  
}  
Cliente 3 {  
  l.lock();  
  supply_('item2',5);  
  l.unlock();  
}
```

Lock: T1	em espera p/ lock:
Wait-Set:	registro: T1 = 3

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	4	4	5

Cliente 1: consume (['item2', 'item3', 'item4'])

Cliente 2: consume (['item2'])

Cliente 3: supply ('item3', 5)

Cliente 3: supply ('item2', 5)

T₁

```

Cliente 1 {
    l.lock();
    preconsume_('item2');
    preconsume_('item3');
    preconsume_('item4');
    consume_('item2');
    consume_('item3');
    consume_('item4');
    l.unlock();
}

```

T₂

```

Cliente 2 {
    l.lock();
    preconsume_('item2');
    consume_('item2');
}

```

```
...
this.get('item4').q -= 1;
...
```

T₃

```

Cliente 3 {
    l.lock();
    supply_('item3',5);
    l.unlock();
}

Cliente 3 {
    l.lock();
    supply_('item2',5);
    l.unlock();
}

```

Lock:	<i>em espera p/ lock:</i>
Wait-Set:	registro: $TI = 3$

String	'item1'	'item2'	'item3'	'item4'
Item.quantity	10	4	4	4

Sugestões

- Tornar o stock de cada produto limitado
- Suportar o acesso concorrente ao armazém
- Adicionar os métodos de registar e remover produtos do armazém