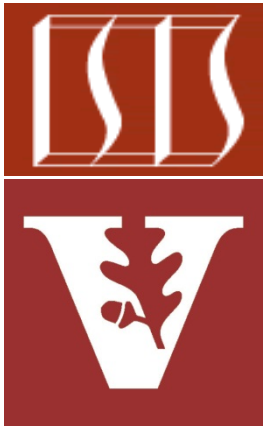
Android Concurrency: The Monitor Object Pattern (Part 1)



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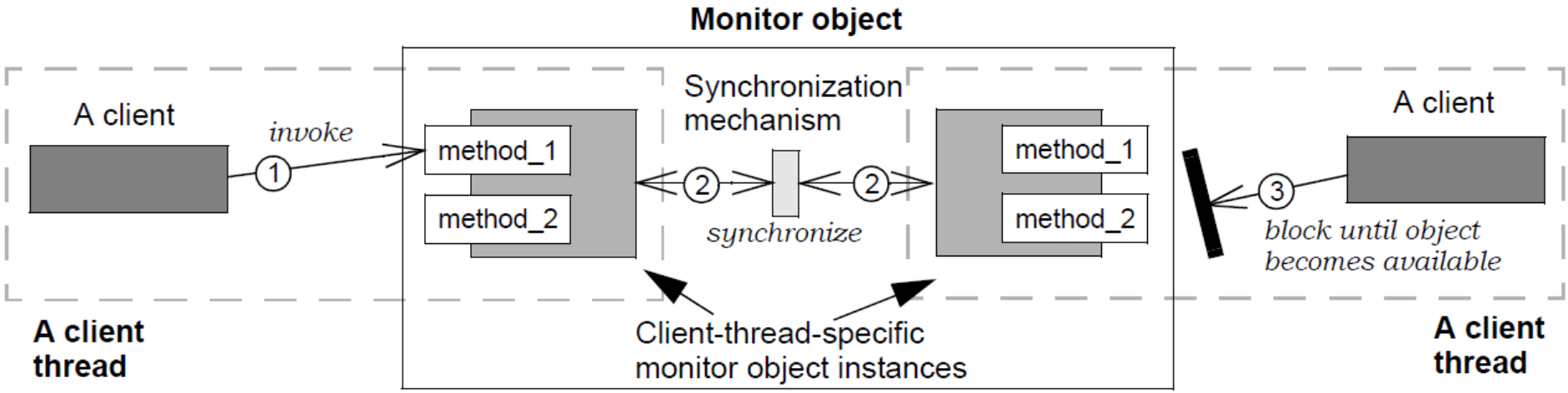
Learning Objectives in this Part of the Module

- Understand the *Monitor Object* pattern

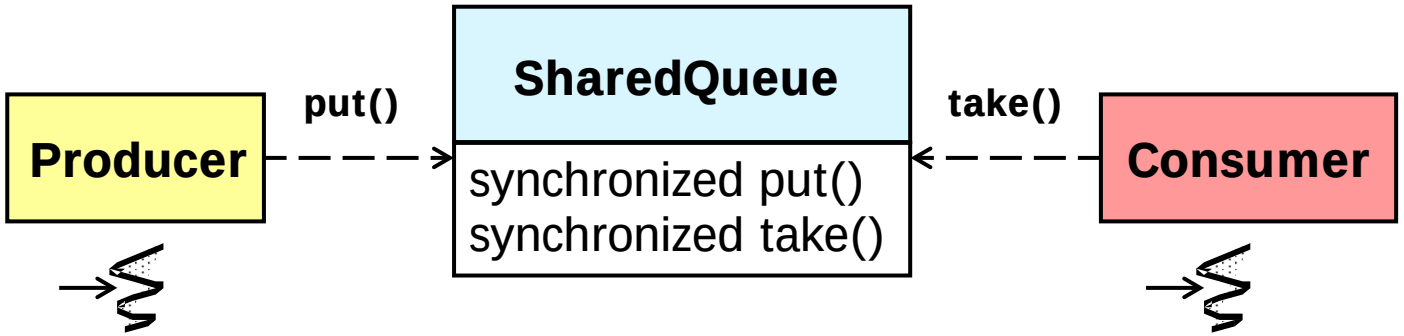


See www.dre.vanderbilt.edu/~schmidt/PDF/monitor.pdf for *Monitor Object*

Challenge: Implementing a Blocking Queue

Context

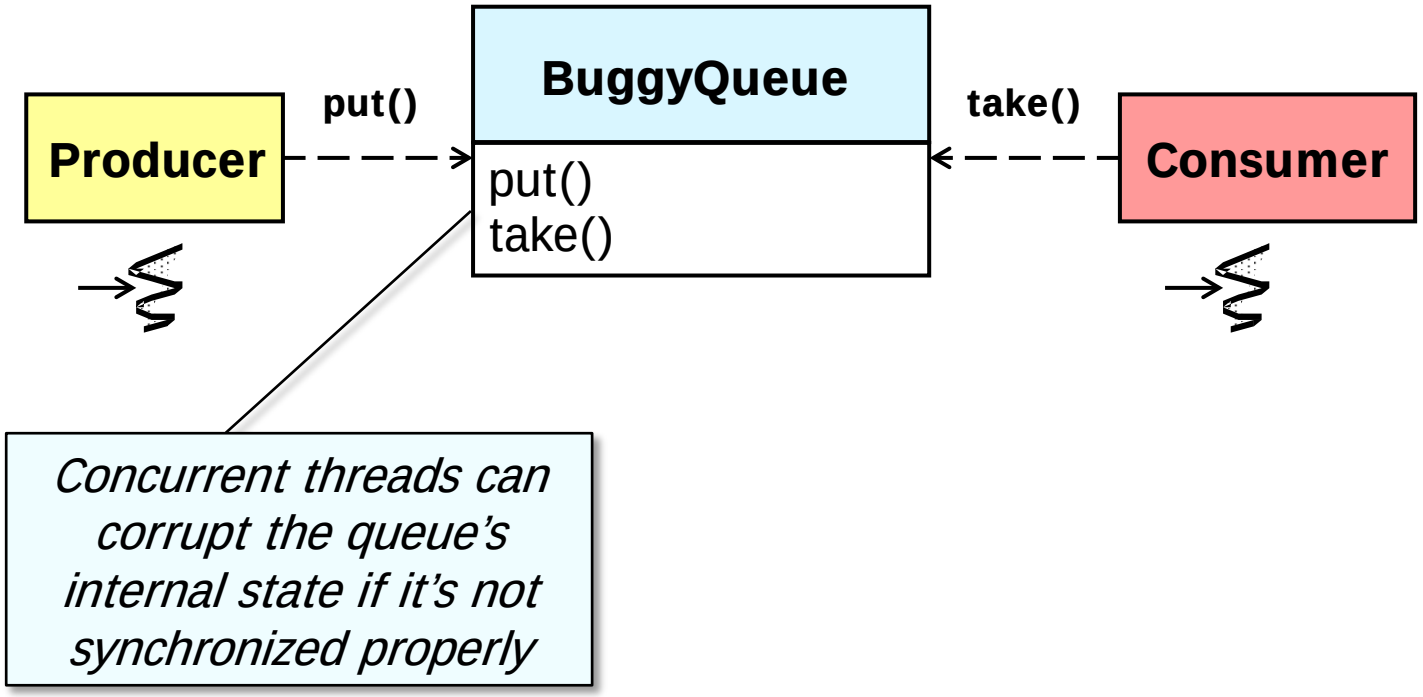
- Concurrent apps/services that need to coordinate interactions between producer & consumer threads via a shared queue



Challenge: Implementing a Blocking Queue

Problems

- Naïve implementations incur race conditions or "busy waiting" when multiple threads put/take items into/from the shared queue



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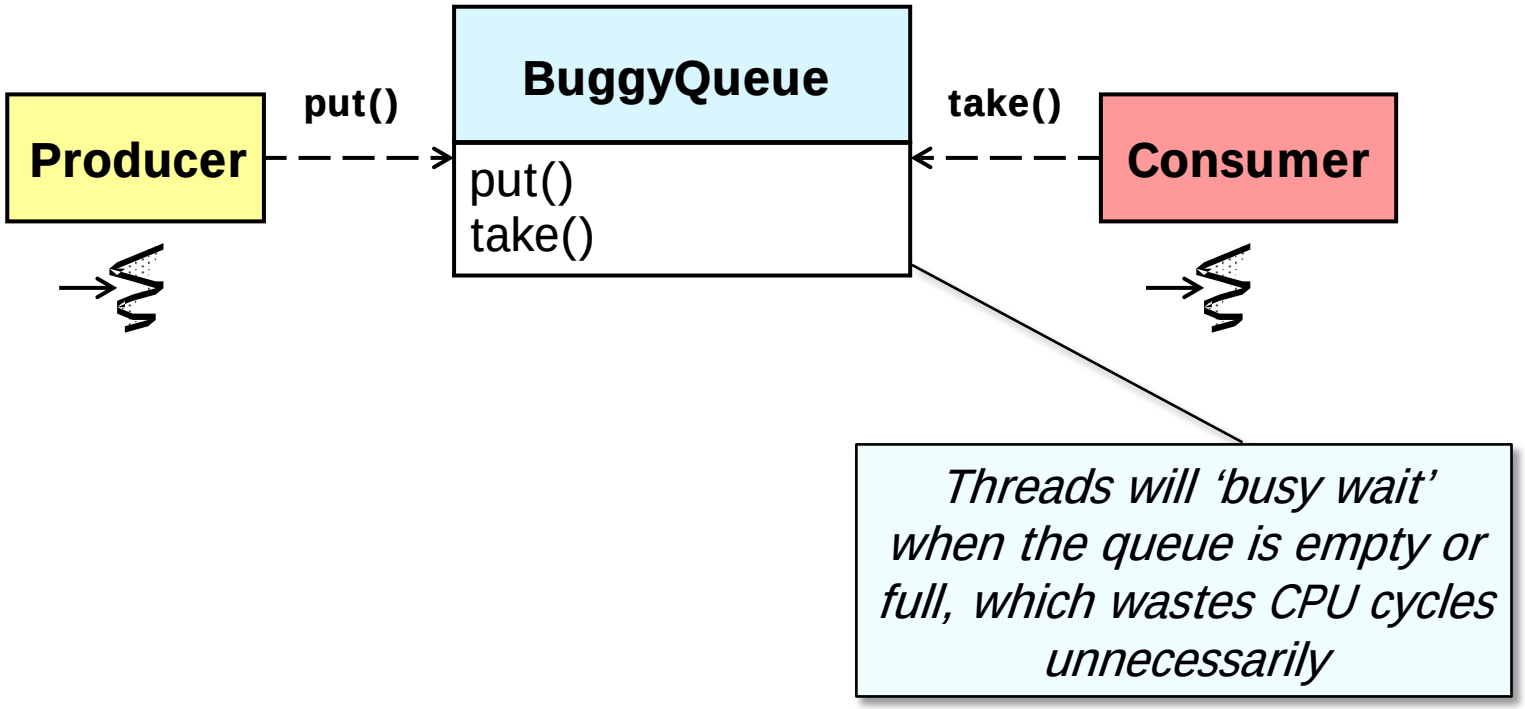
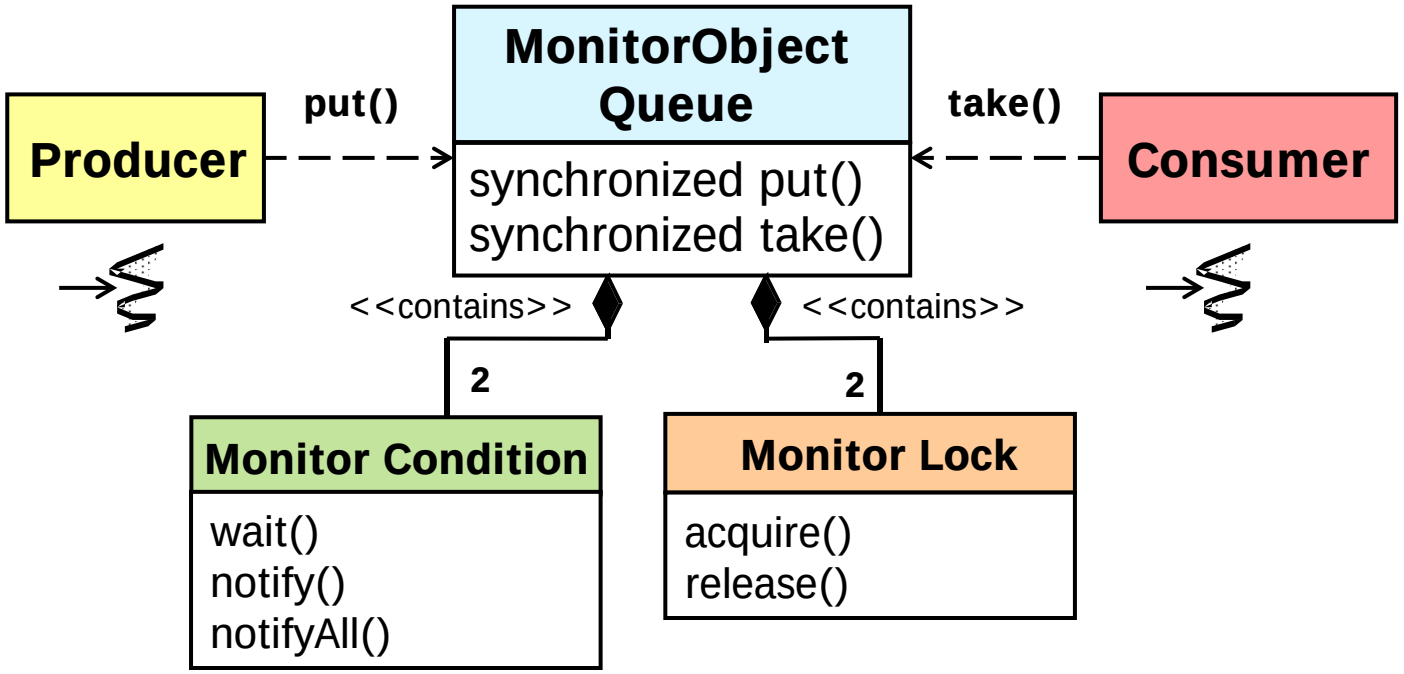


Challenge: Implementing a Blocking Queue

Solution

- Apply the *Monitor Object* pattern to synchronize the shared queue efficiently & conveniently



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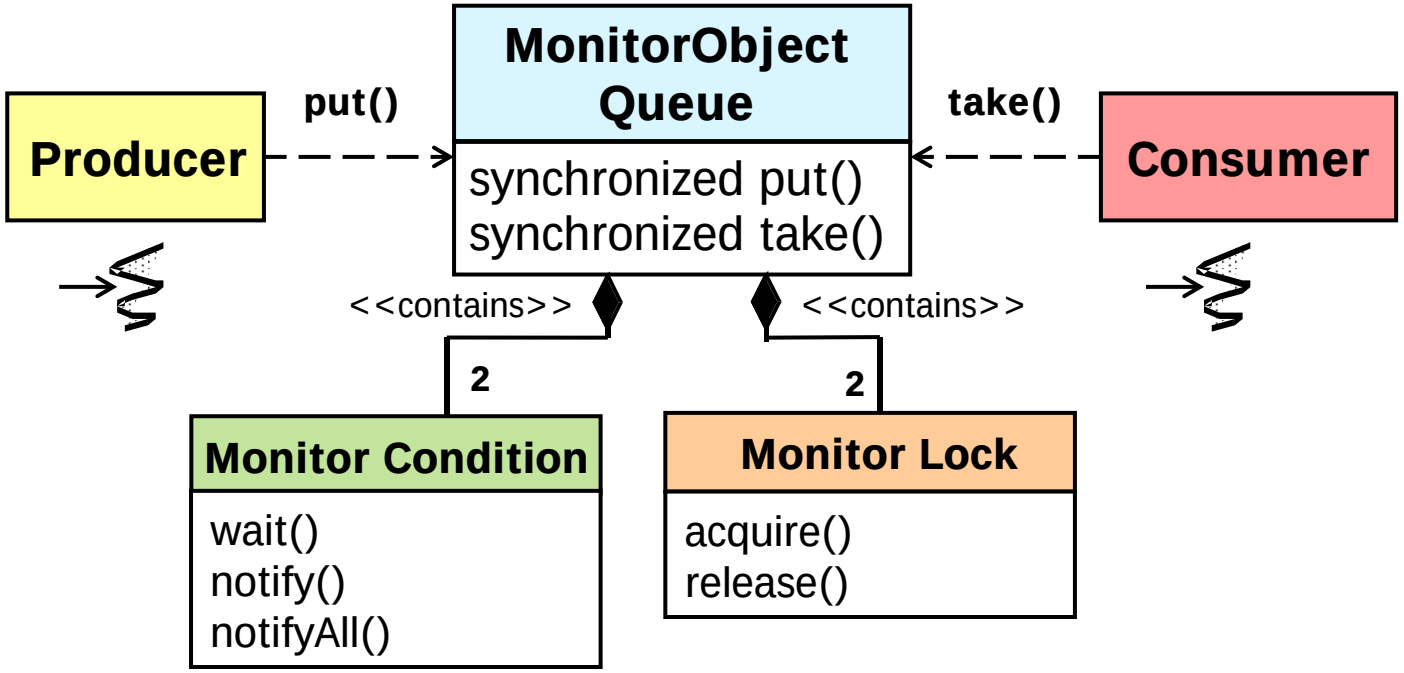

See earlier parts on “Java ConditionObject” & “Java Built-in Monitor Objects”

Challenge: Implementing a Blocking Queue

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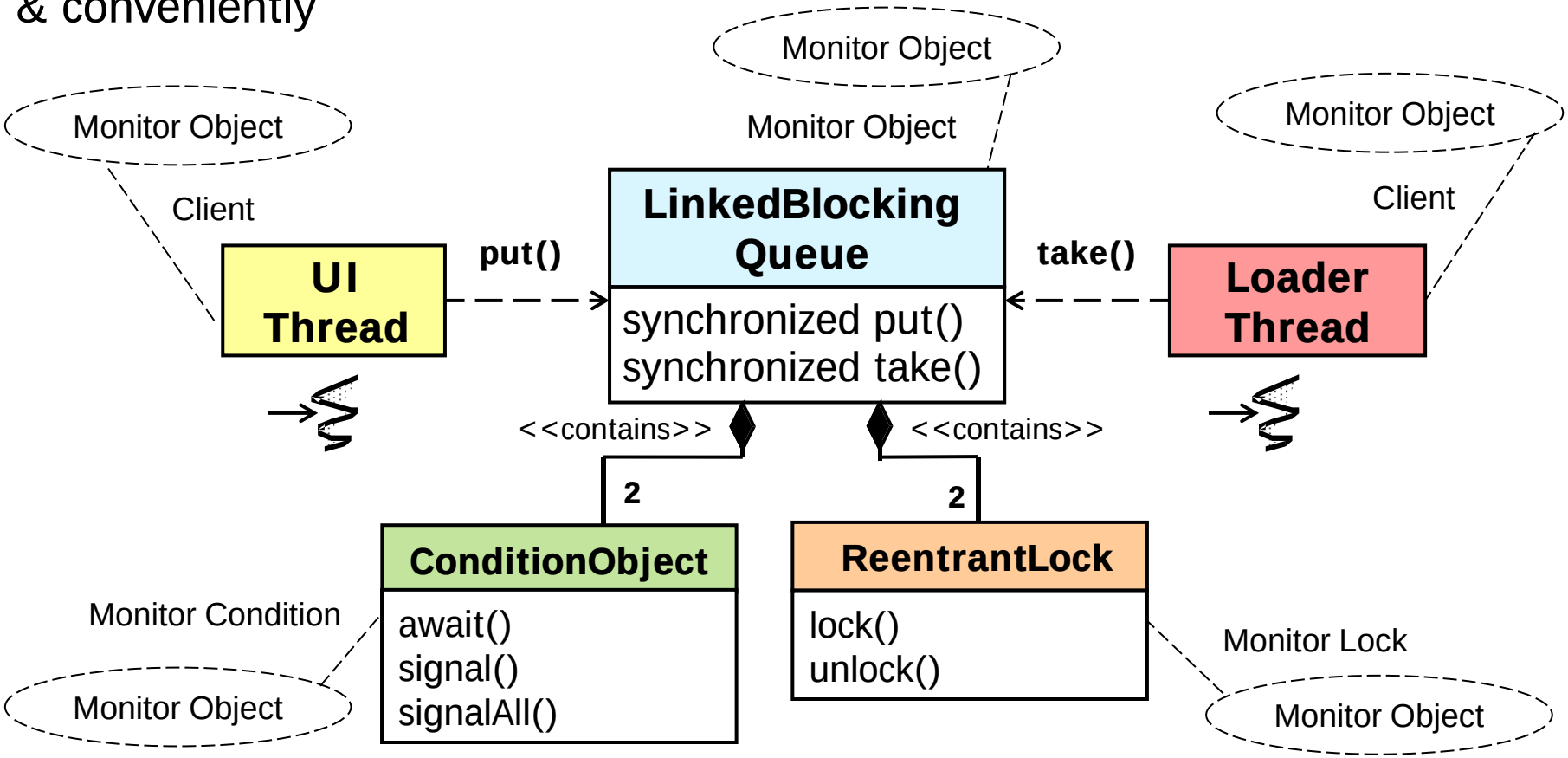

Challenge: Implementing a Blocking Queue

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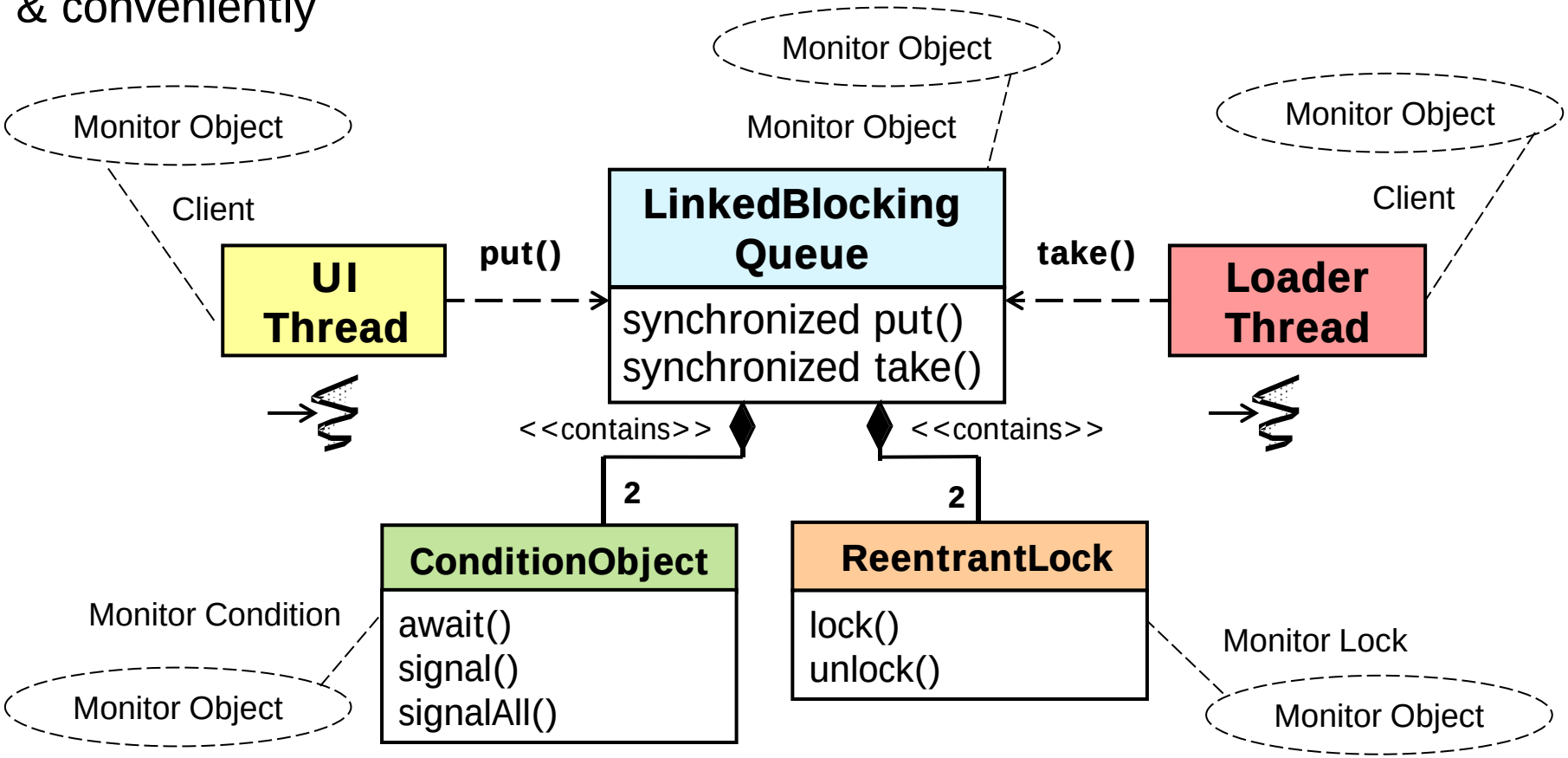


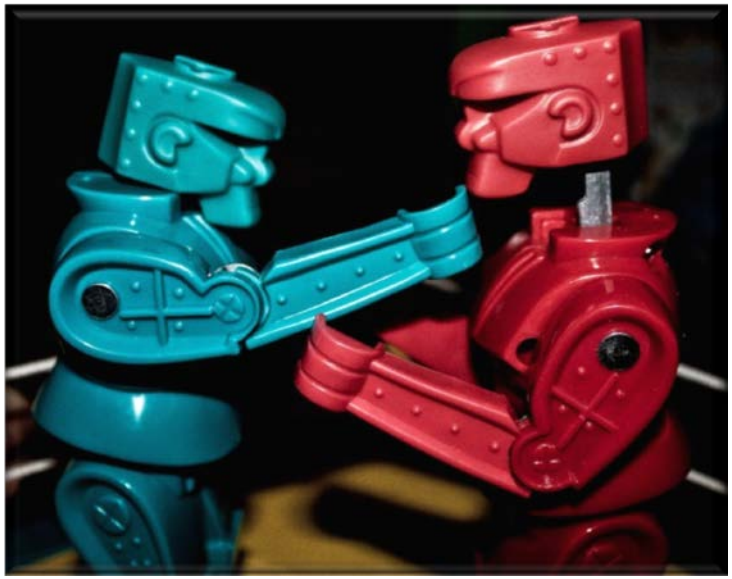
See earlier part on “Java ConditionObject” for ArrayBlockingQueue analysis

Challenge: Implementing a Blocking Queue

Solution

- Apply the *Monitor Object* pattern to synchronize the shared queue efficiently & conveniently

LinkedBlocking Queue
synchronized put() synchronized take()

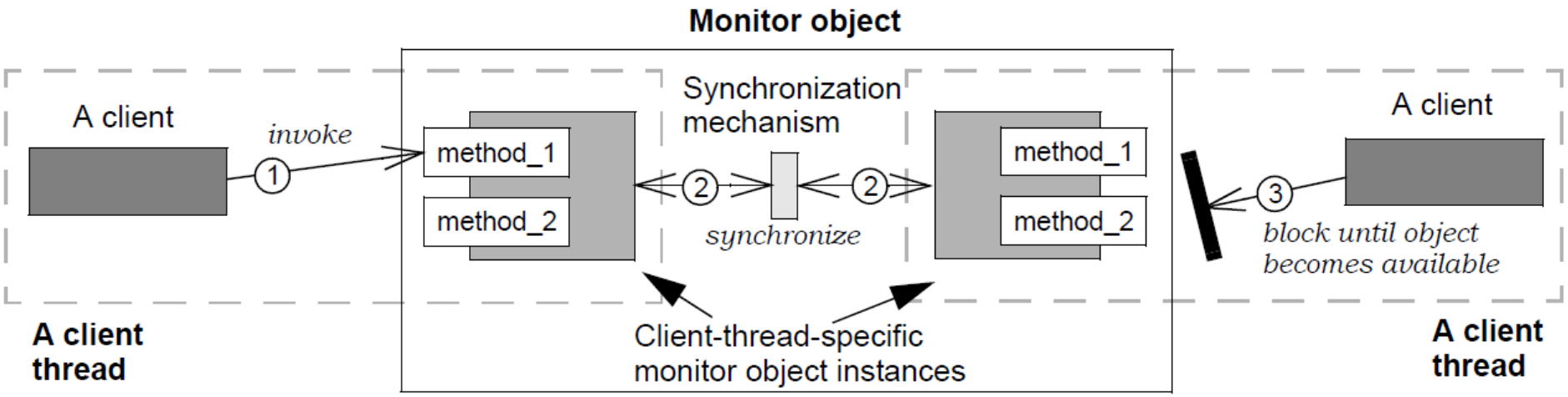


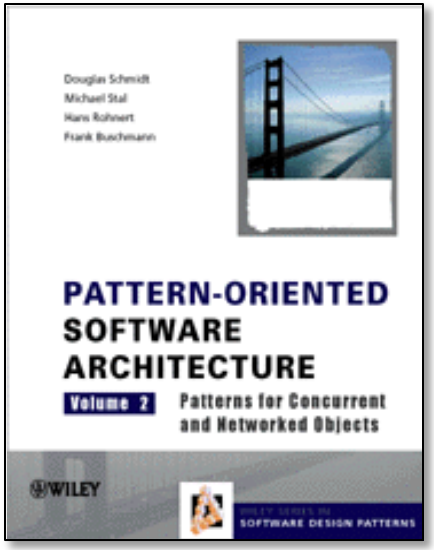
ArrayBlock Queue
synchronized put() synchronized take()

www.javacodegeeks.com/2010/09/java-best-practices-queue-battle-and.html

Intent & Applicability of the Monitor Object Pattern

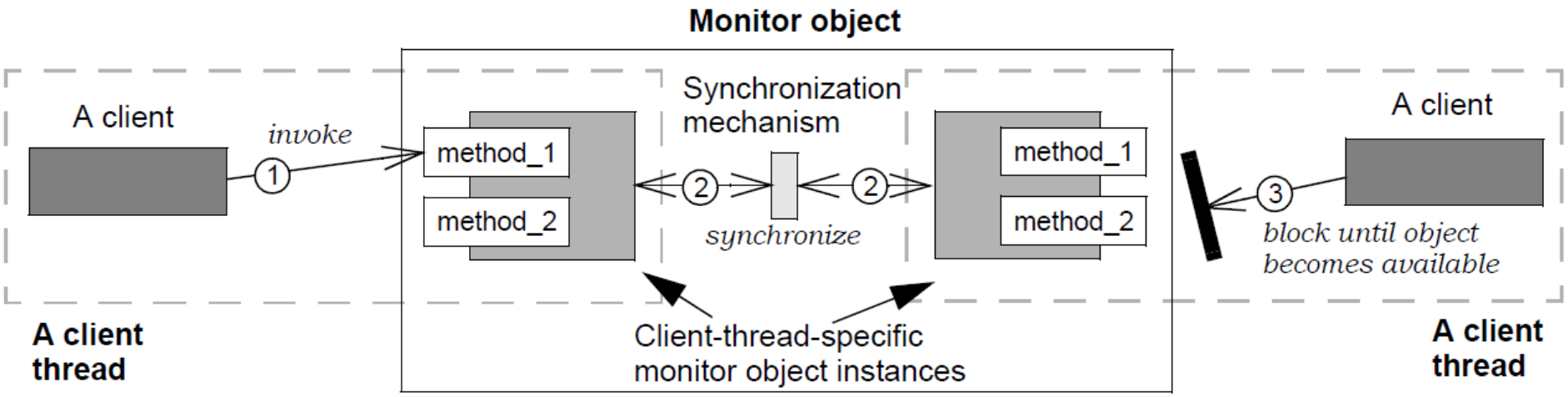
Monitor Object POSA2 Concurrency





www.dre.vanderbilt.edu/~schmidt/POSA/POSA2 has more on the POSA2 book

Monitor Object POSA2 Concurrency



Intent

- Synchronizes concurrent method execution to ensure only one method at a time runs within an object

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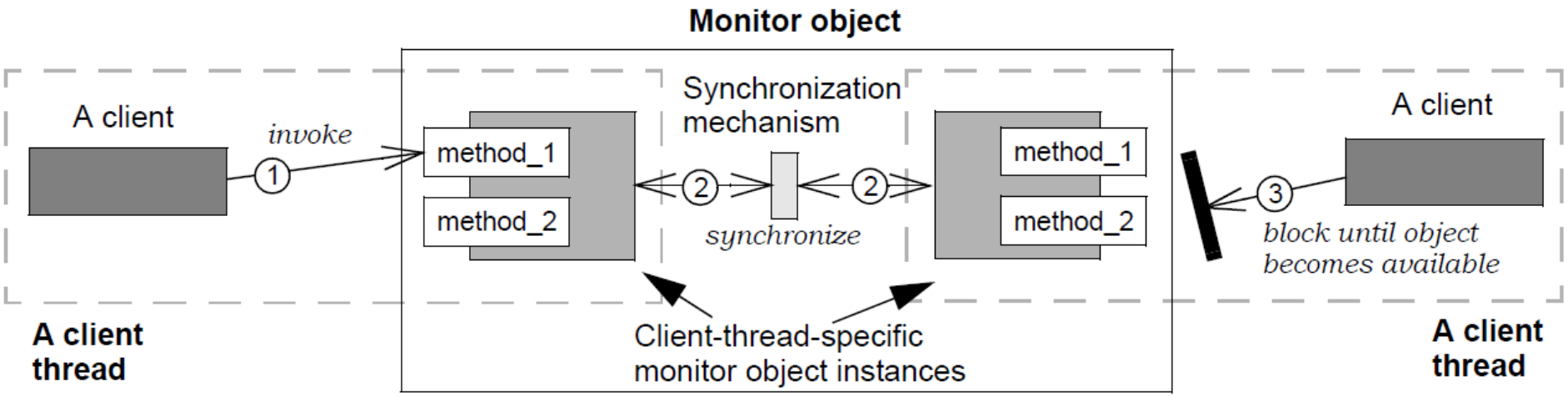
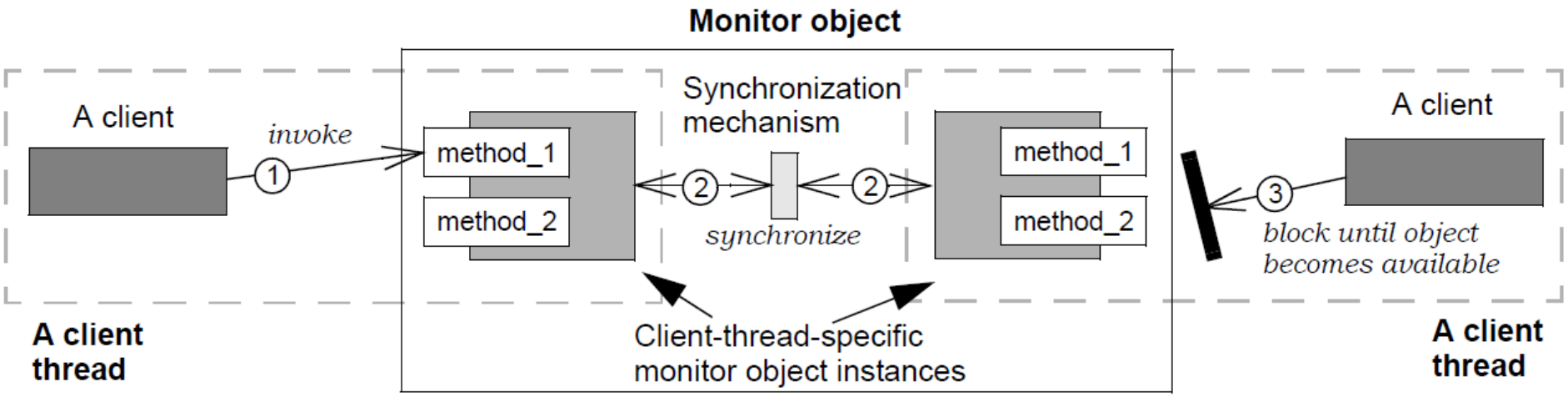


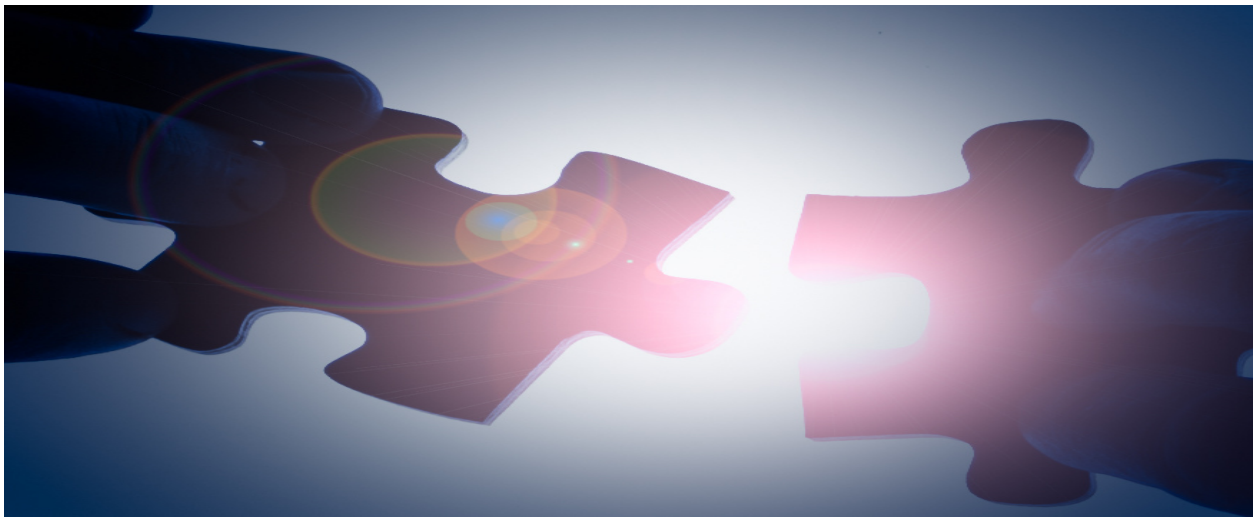
Intent

- Synchronizes concurrent method execution to ensure only one method at a time runs within an object
- Allows an object's methods to cooperatively schedule their execution sequences

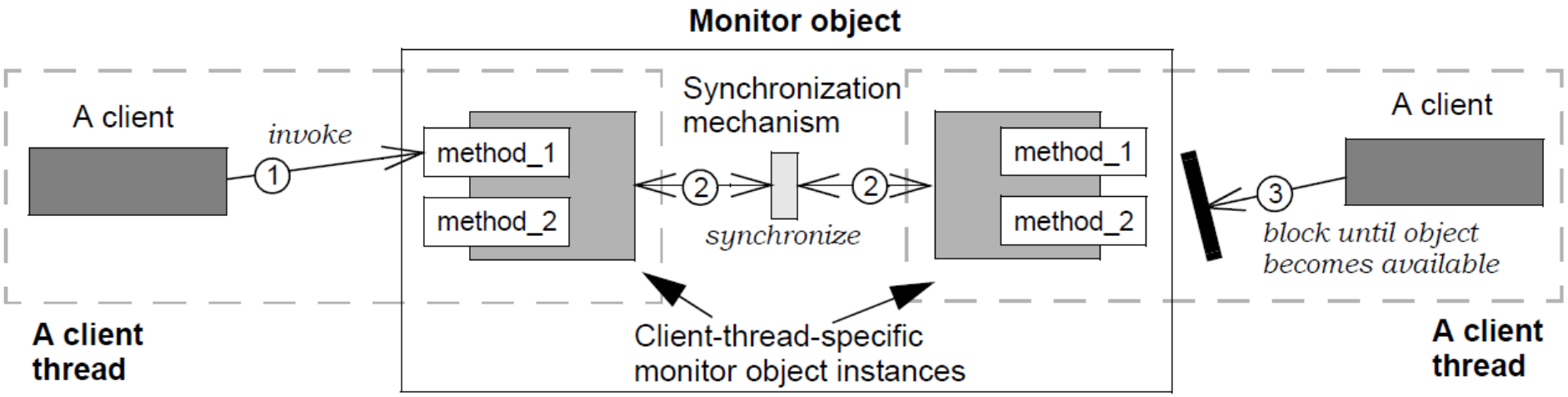
Monitor Object POSA2 Concurrency



Applicability



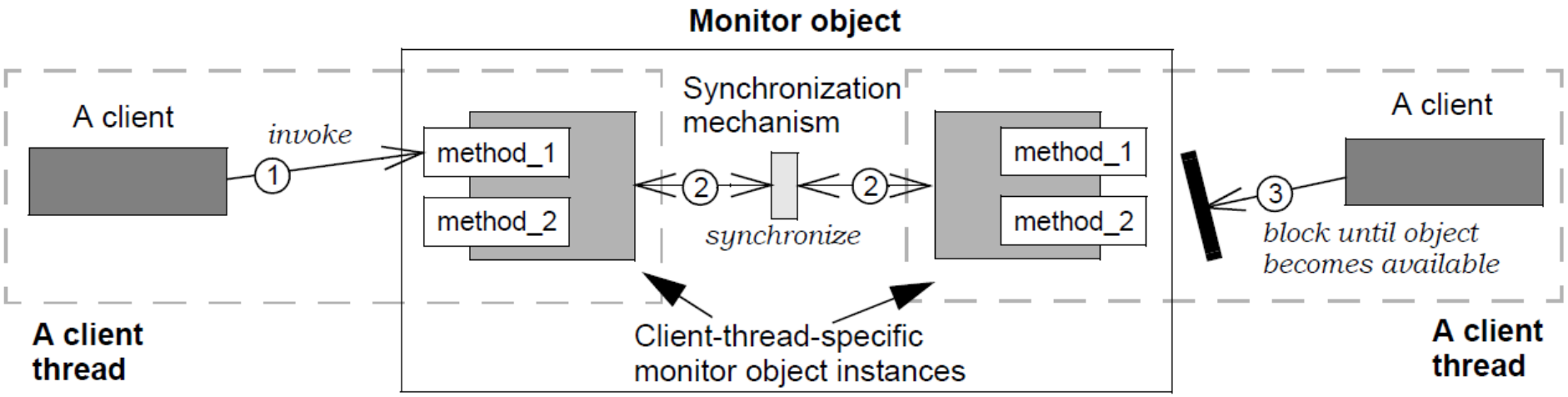
Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries

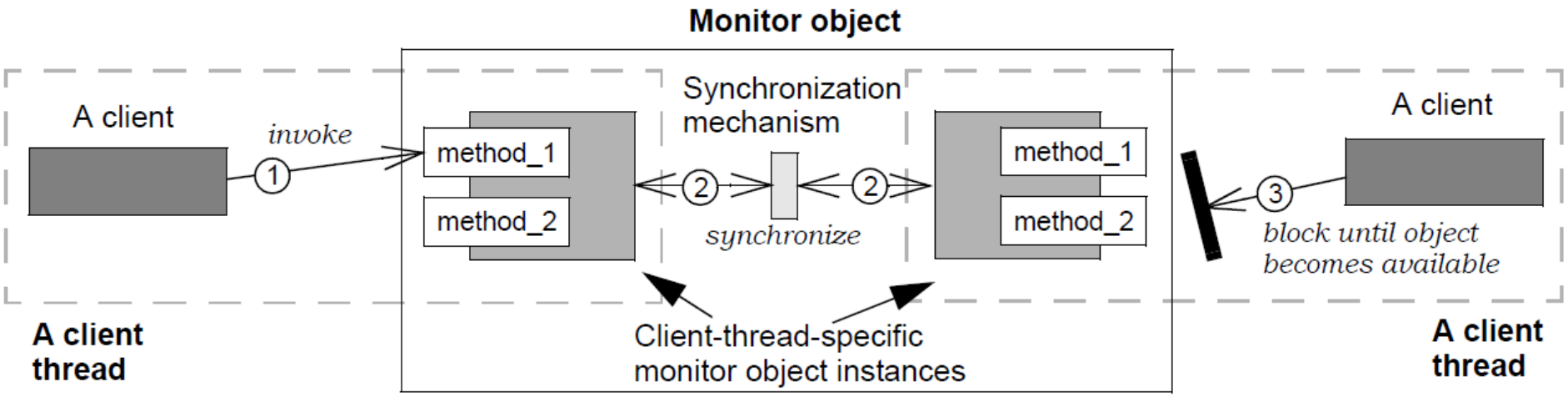
Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries
  - This is an extension of the traditional object-oriented programming model

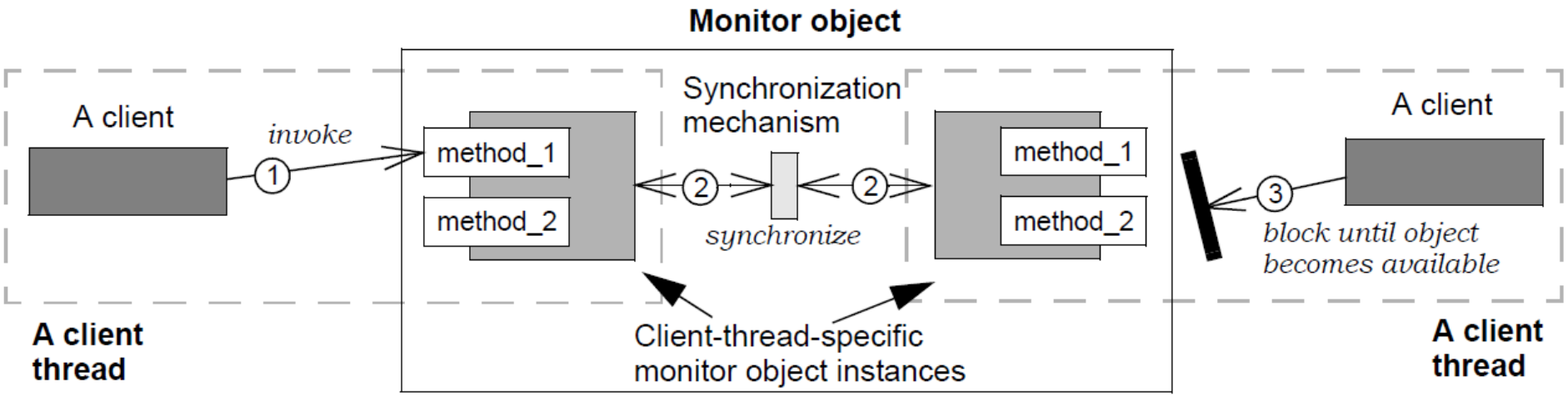
Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries
- When only one method at a time should be active within an object

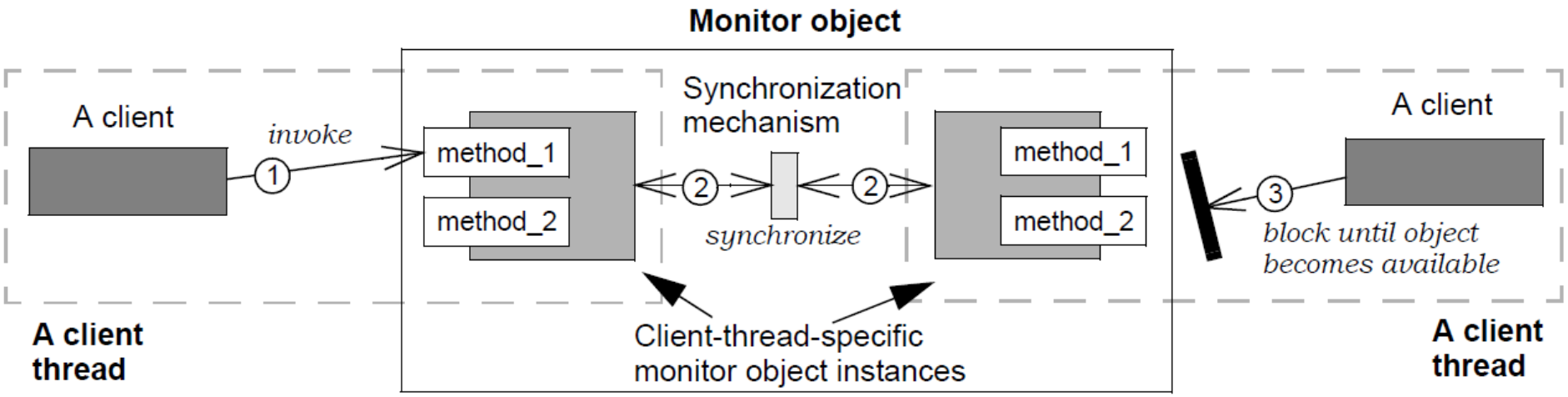
Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries
- When only one method at a time should be active within an object
- When objects should be responsible for transparent method serialization

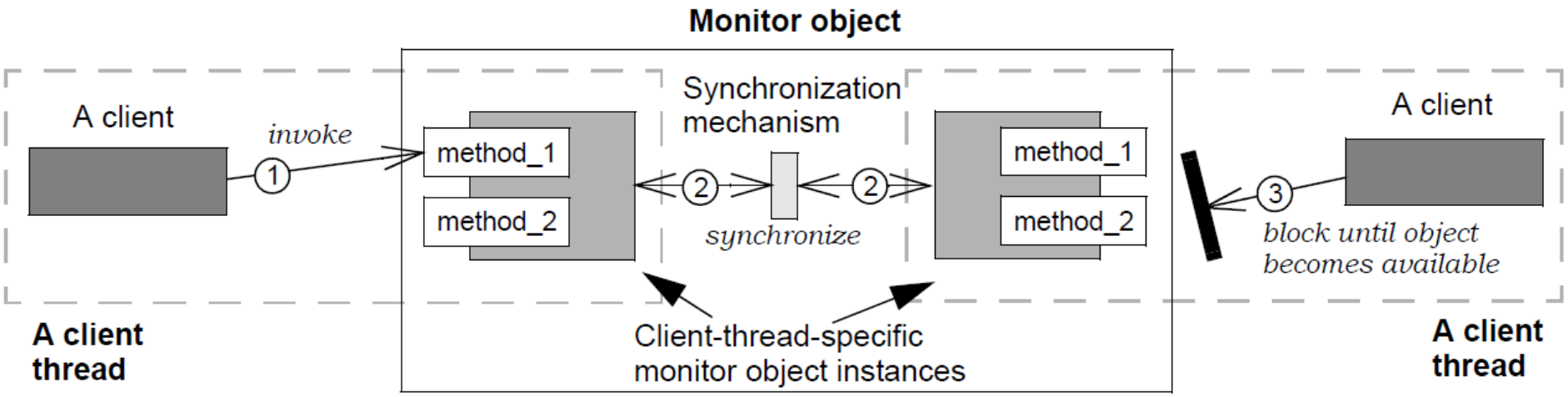
Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries
- When only one method at a time should be active within an object
- When objects should be responsible for transparent method serialization
  - It's tedious & error-prone for clients to explicitly acquire & release low-level synchronization & scheduling mechanisms

Monitor Object POSA2 Concurrency



Applicability

- When an object's interface methods can define its synchronization & scheduling boundaries
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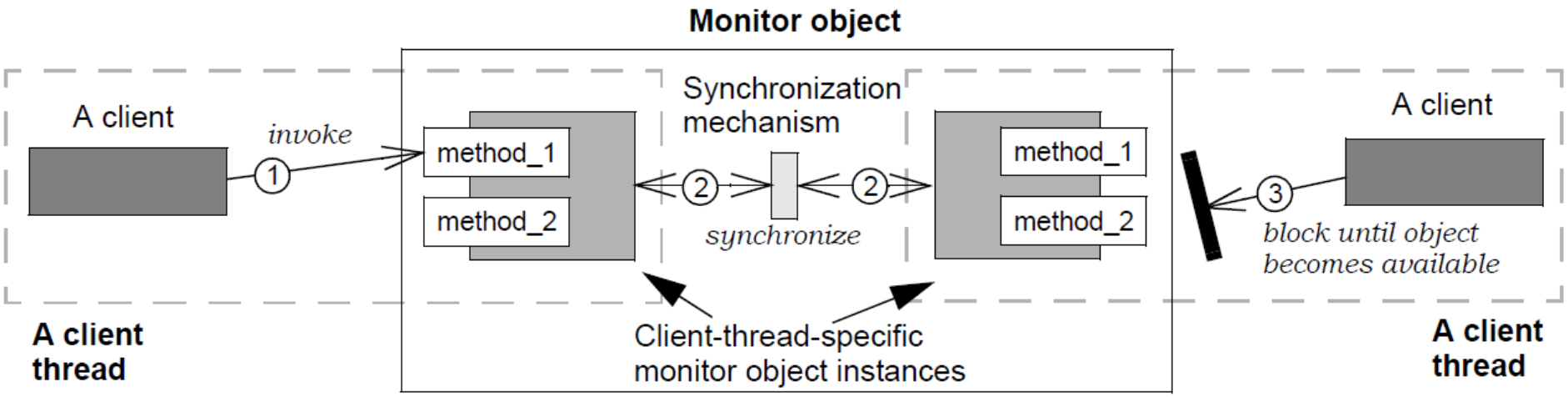
- When objects should be responsible for transparent method serialization
- When an object's methods interact cooperatively via multiple threads

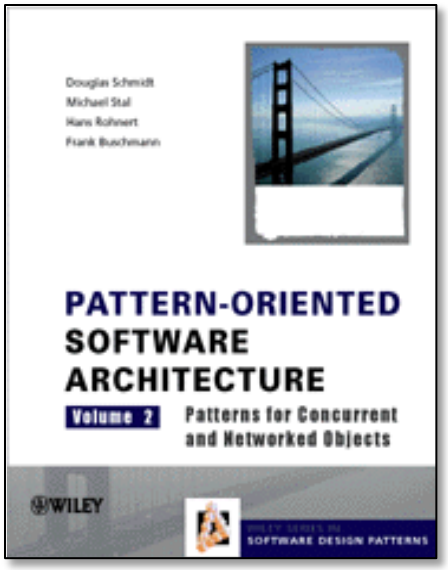
Monitor Object POSA2 Concurrency



Applicability

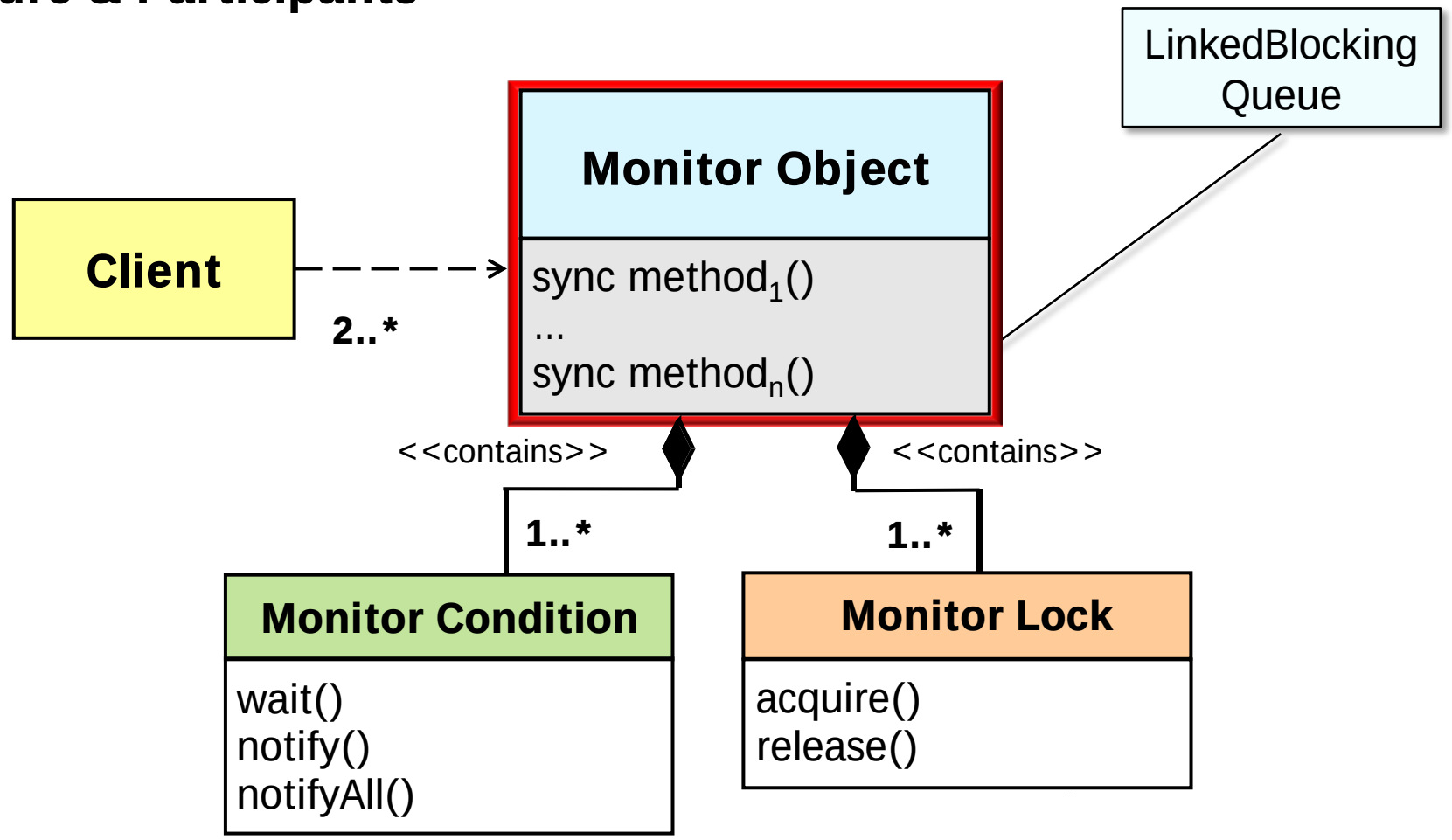
- When an object's interface methods can define its synchronization & scheduling boundaries
- When only one method at a time should be active within an object
- When objects should be responsible for transparent method serialization
- When an object's methods interact cooperatively via multiple threads
  - Object-specific invariants must hold as threads suspend & resume their execution

Structure of the Monitor Object Pattern



Monitor Object POSA2 Concurrency

Structure & Participants



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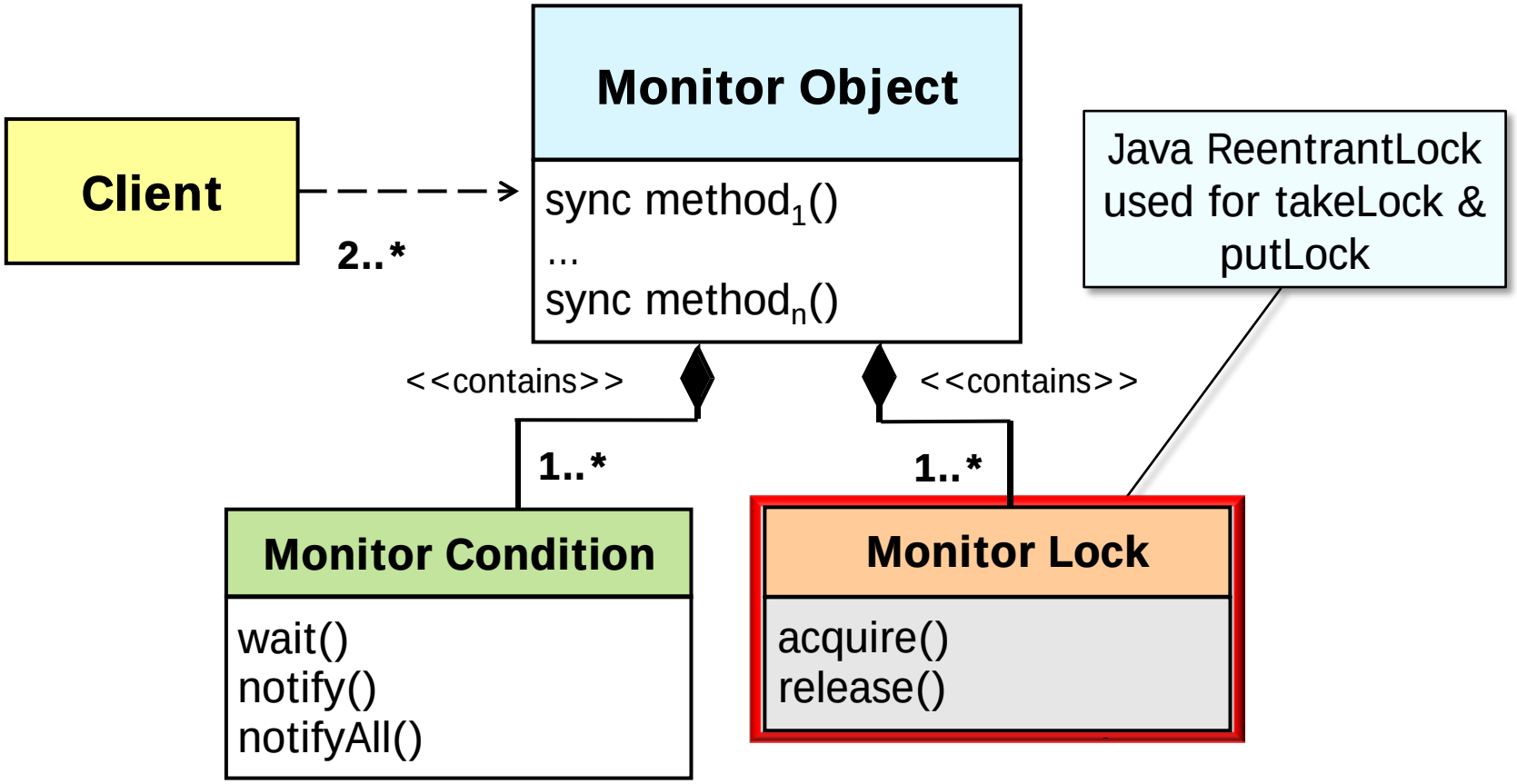

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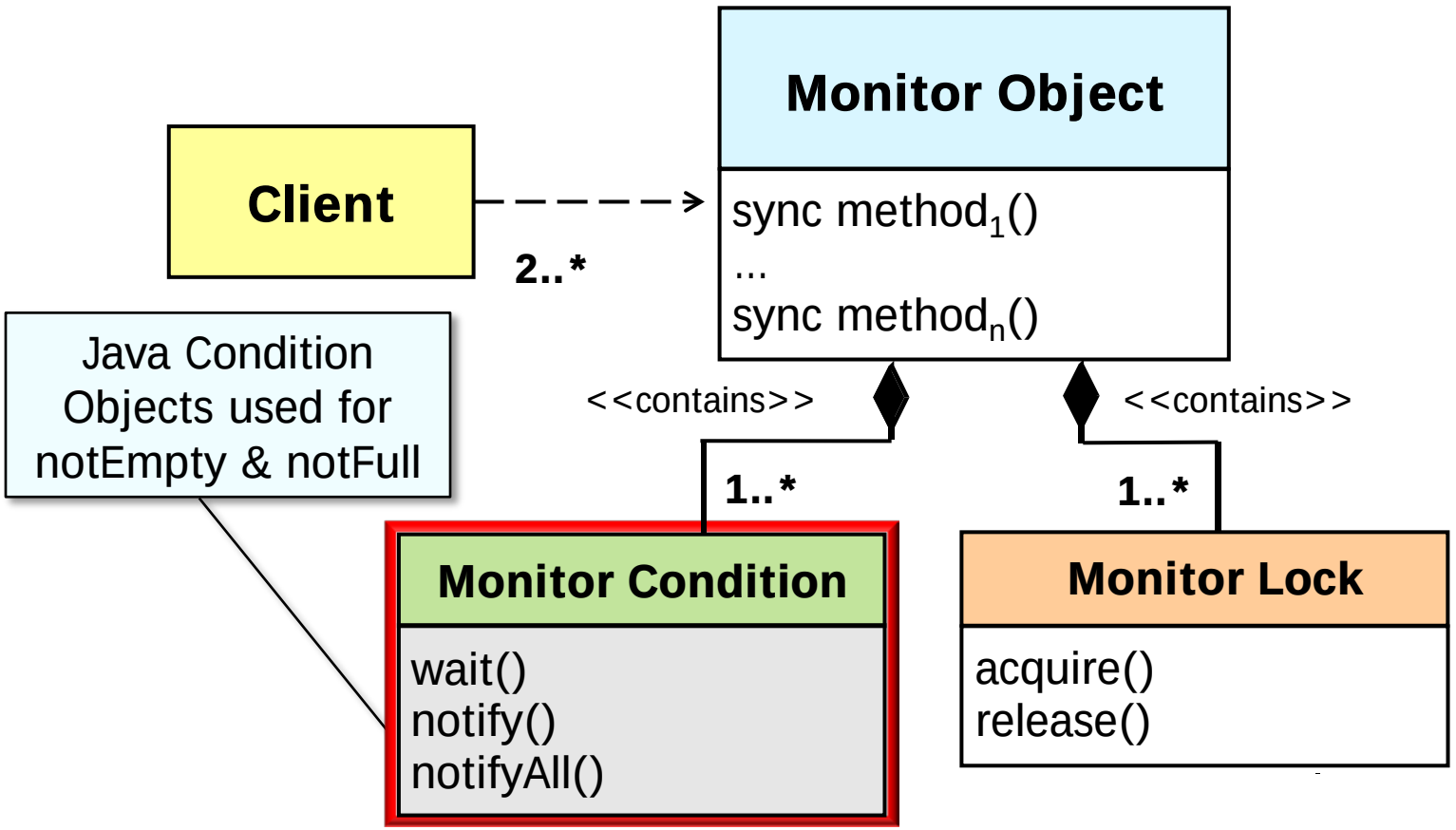
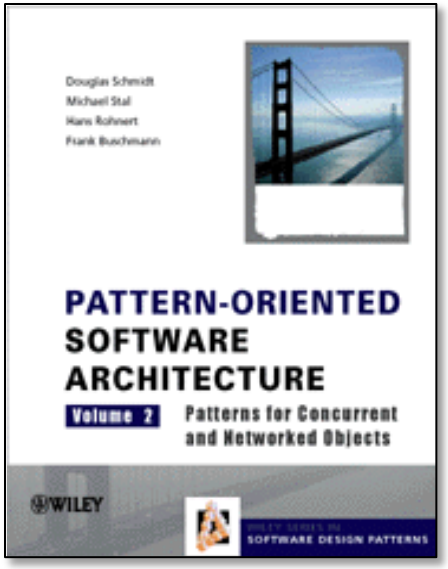


Dynamics of the Monitor Object Pattern



Monitor Object POSA2 Concurrency

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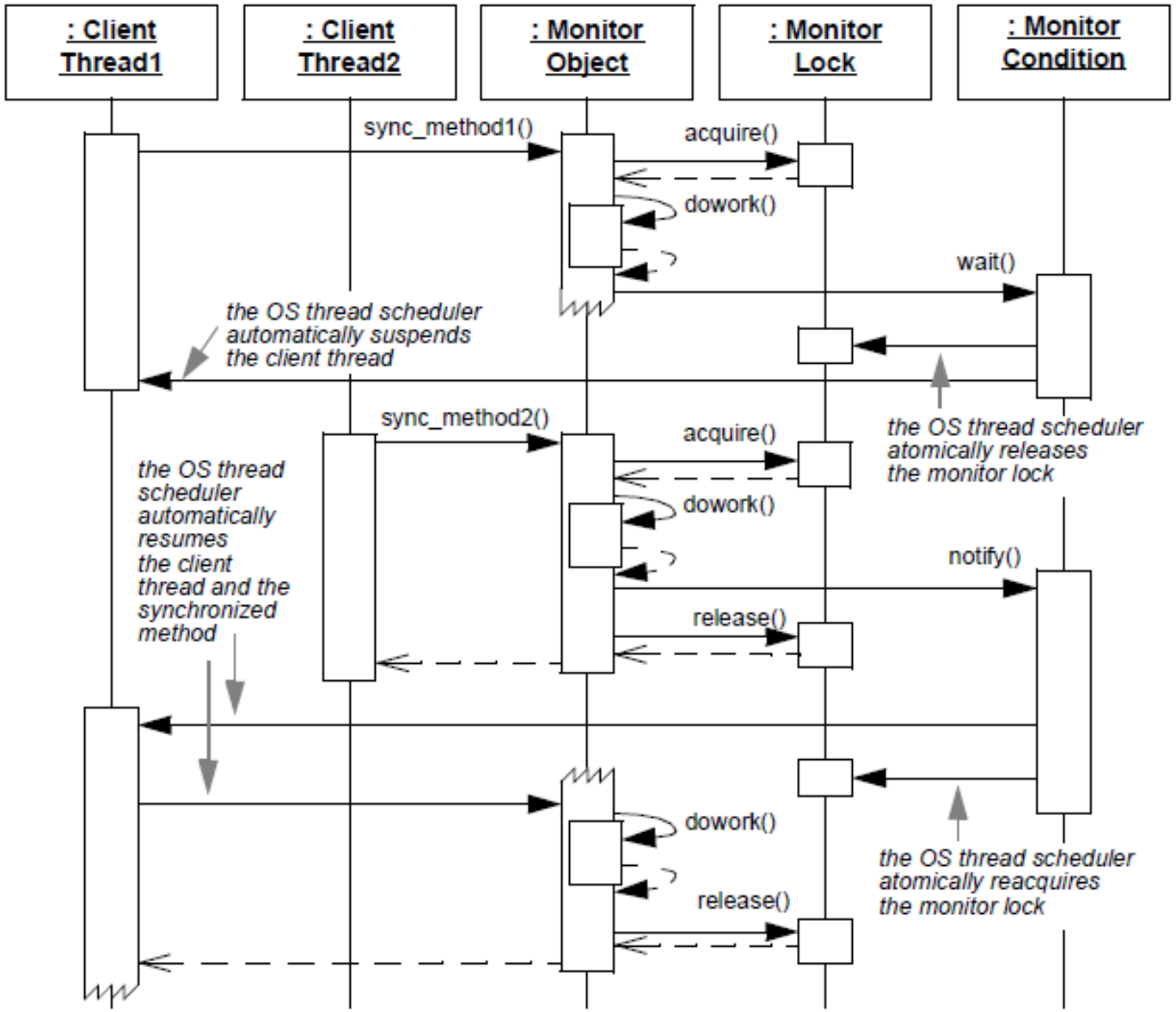

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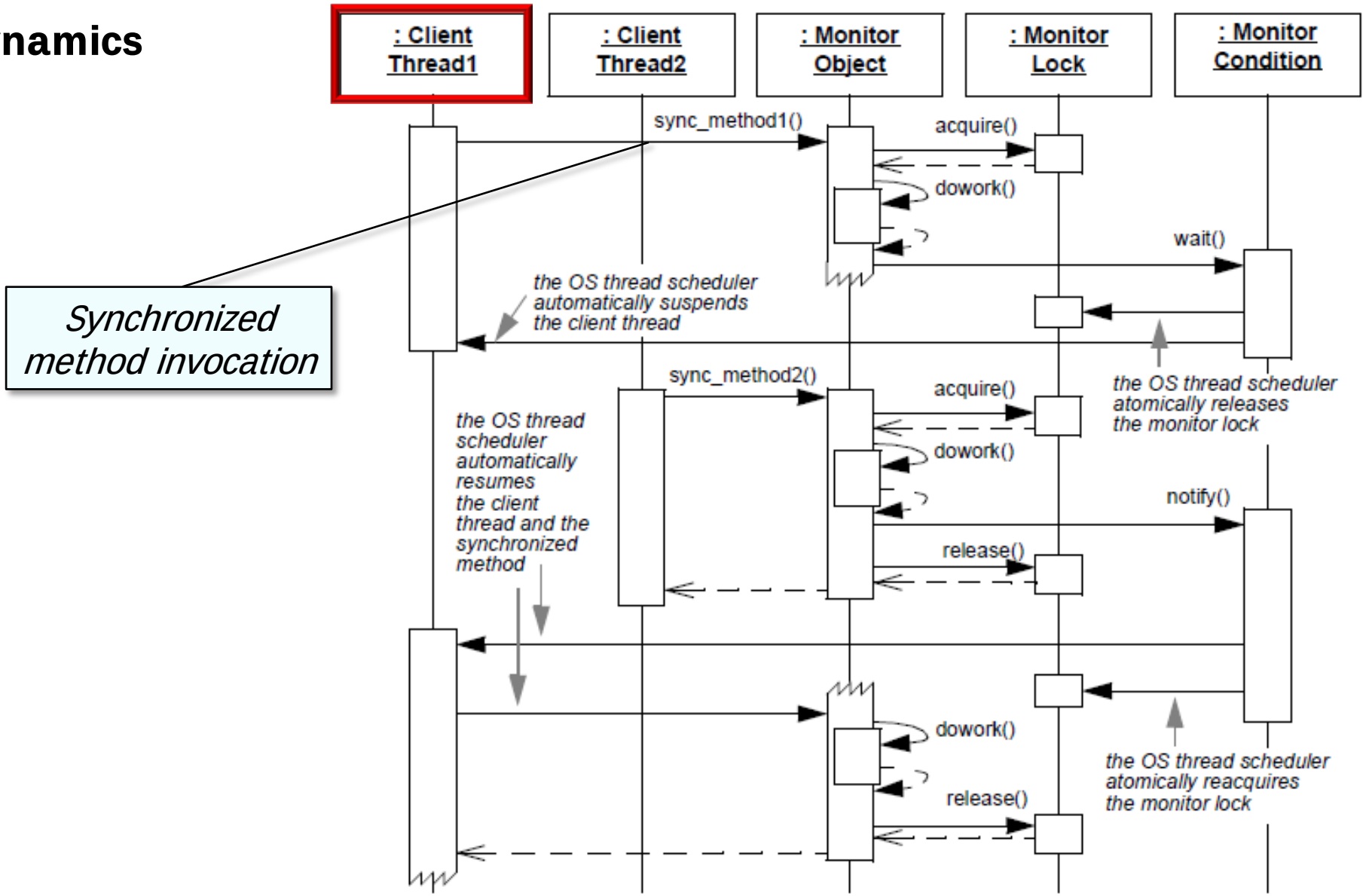

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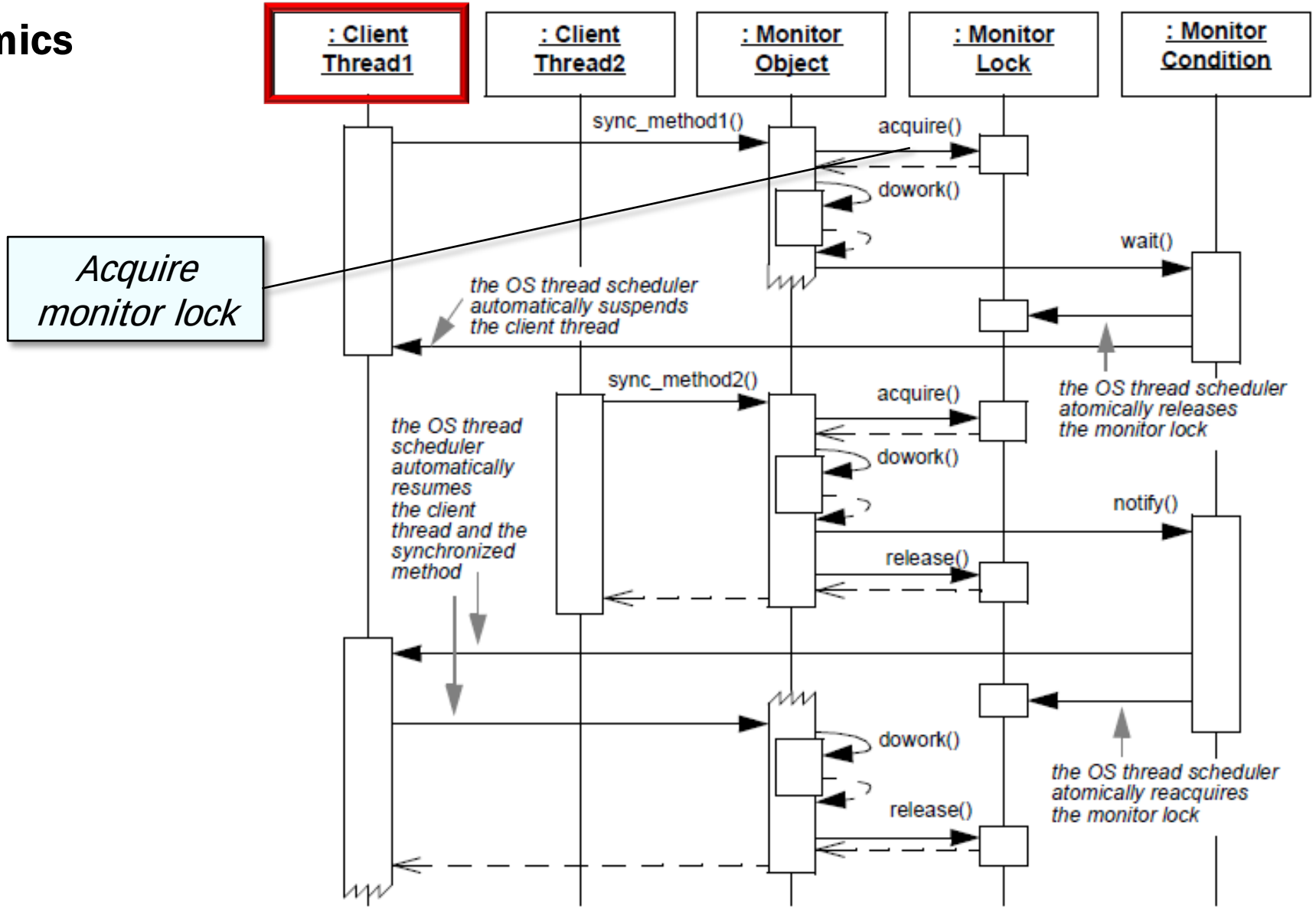

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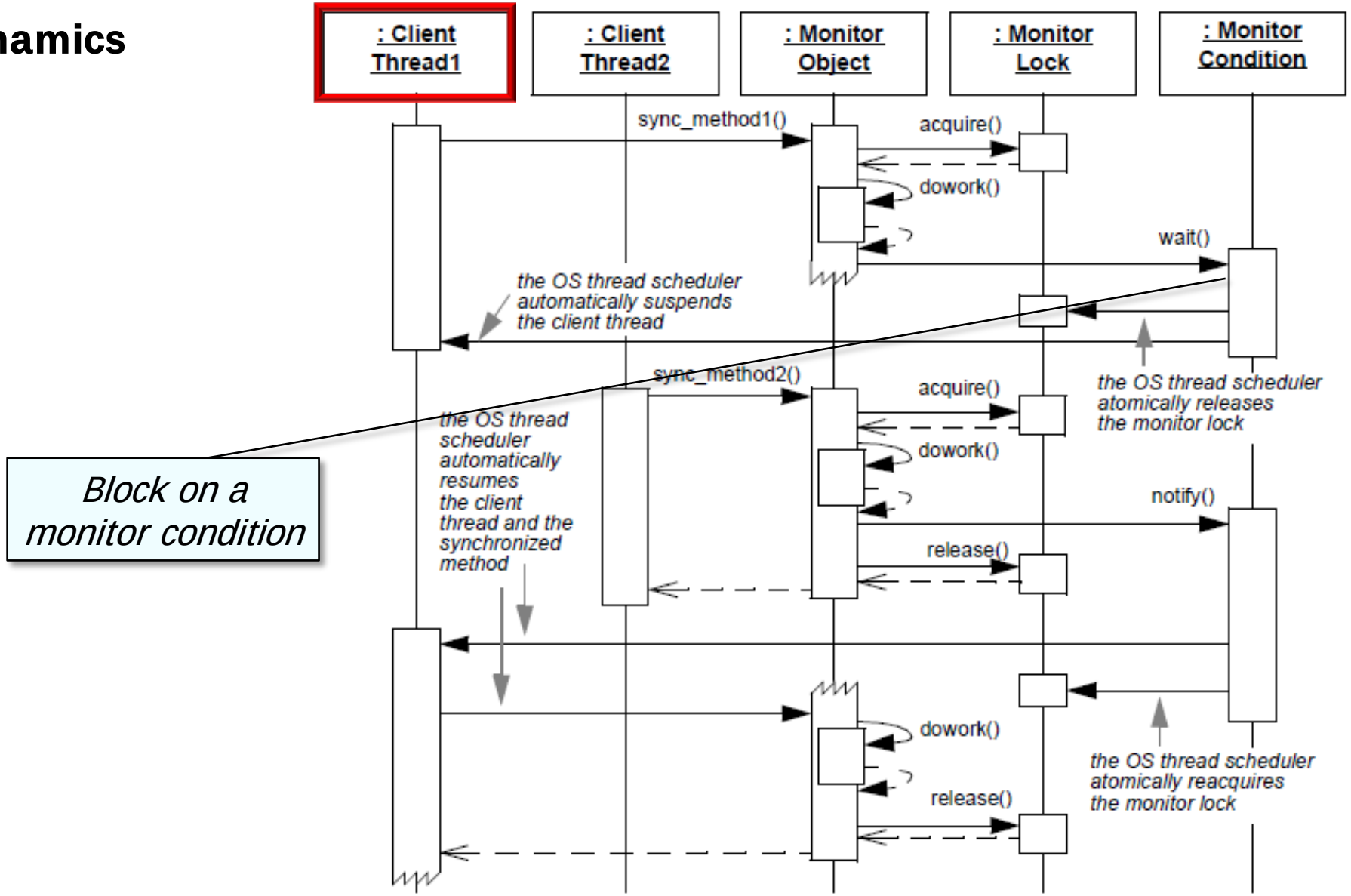

Monitor Object — POSA2 Concurrency

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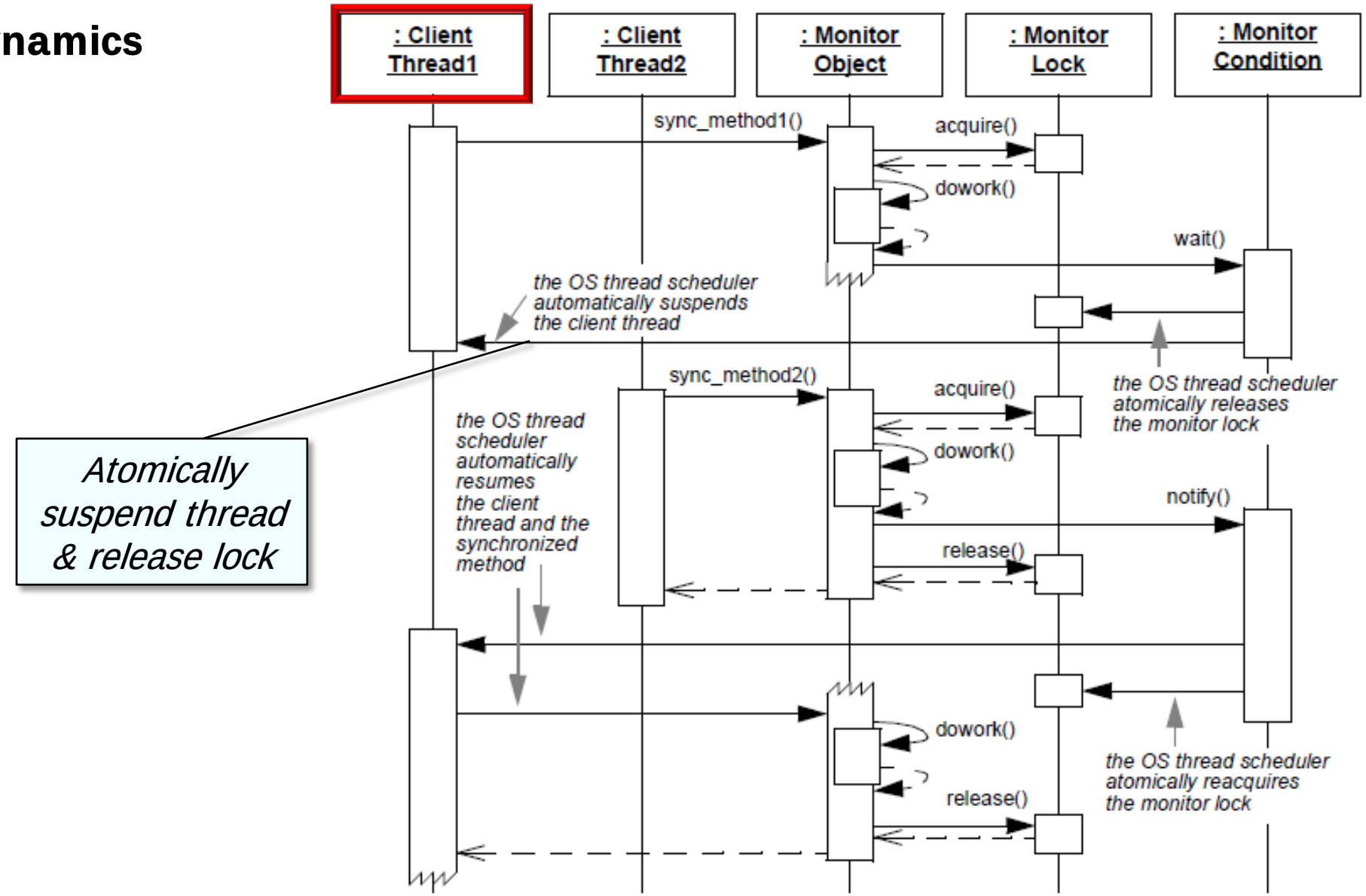

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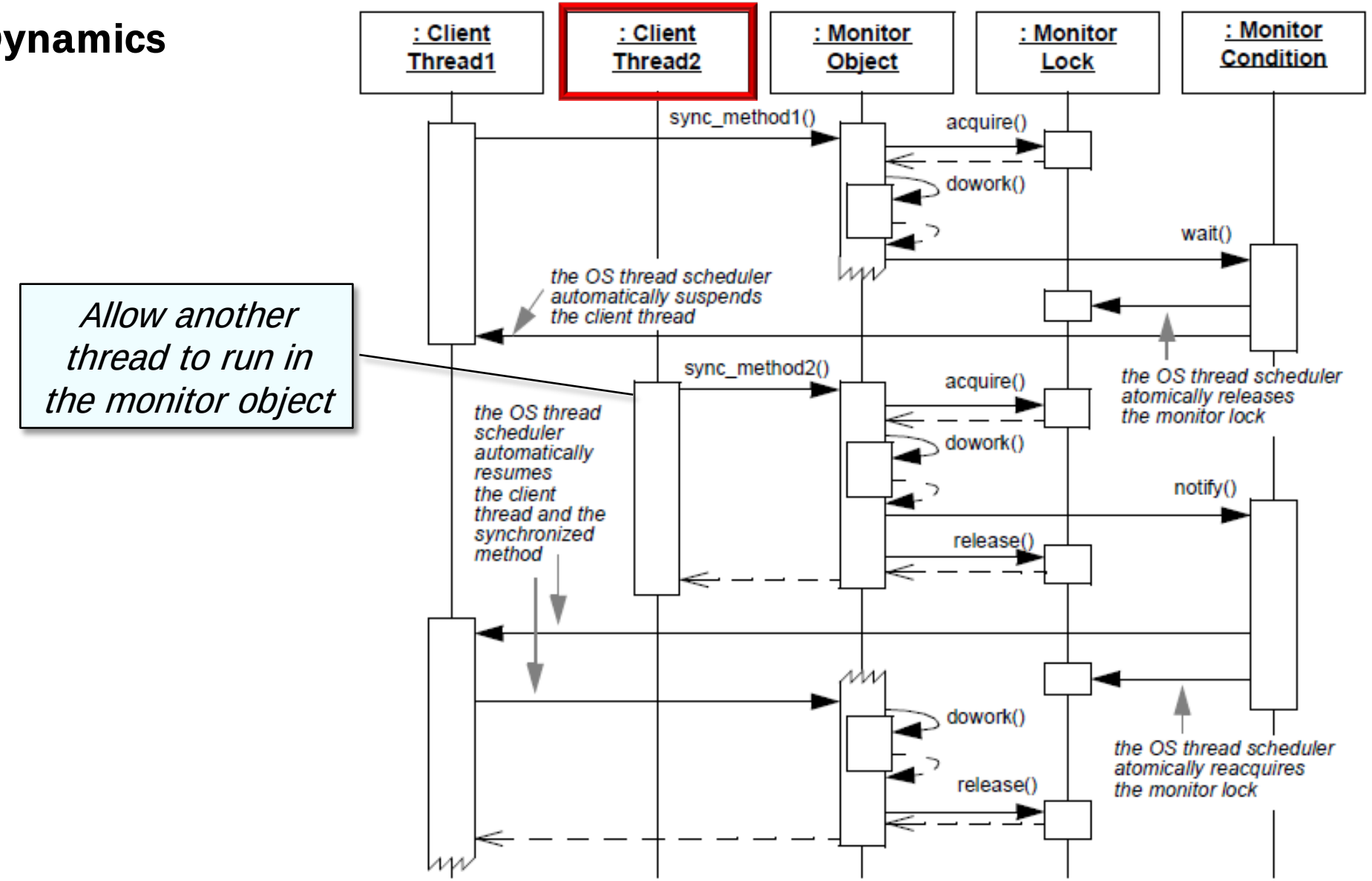

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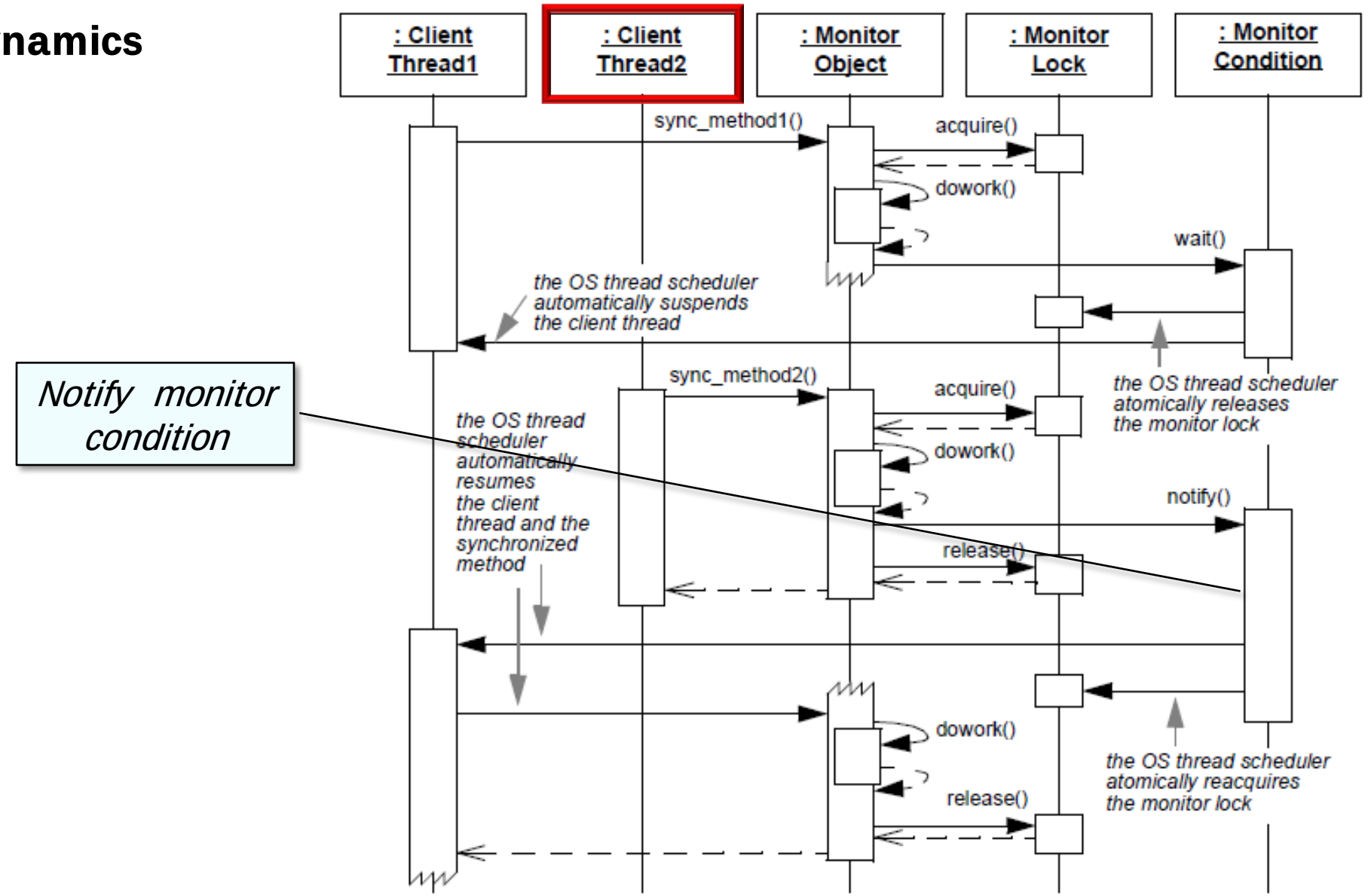

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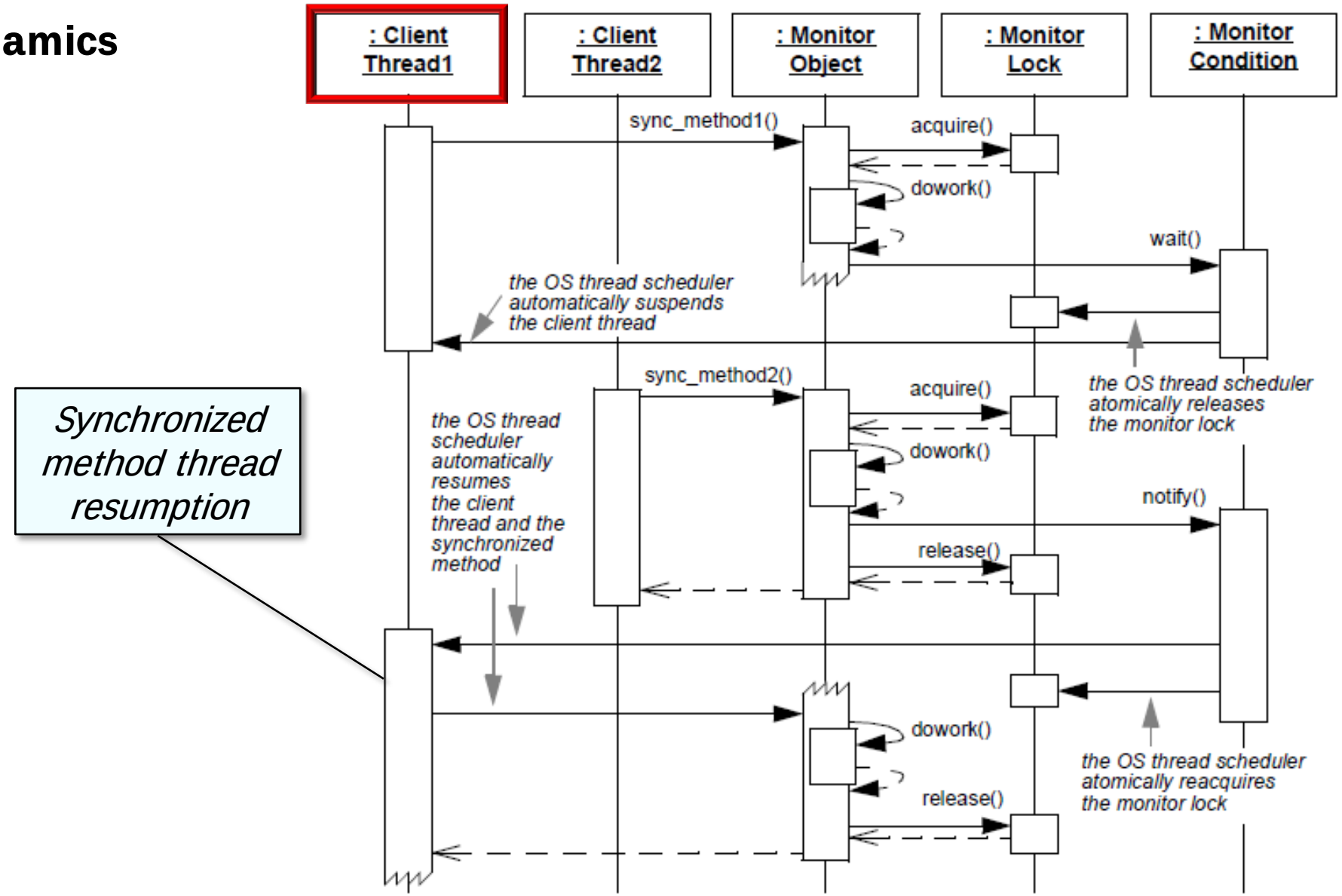

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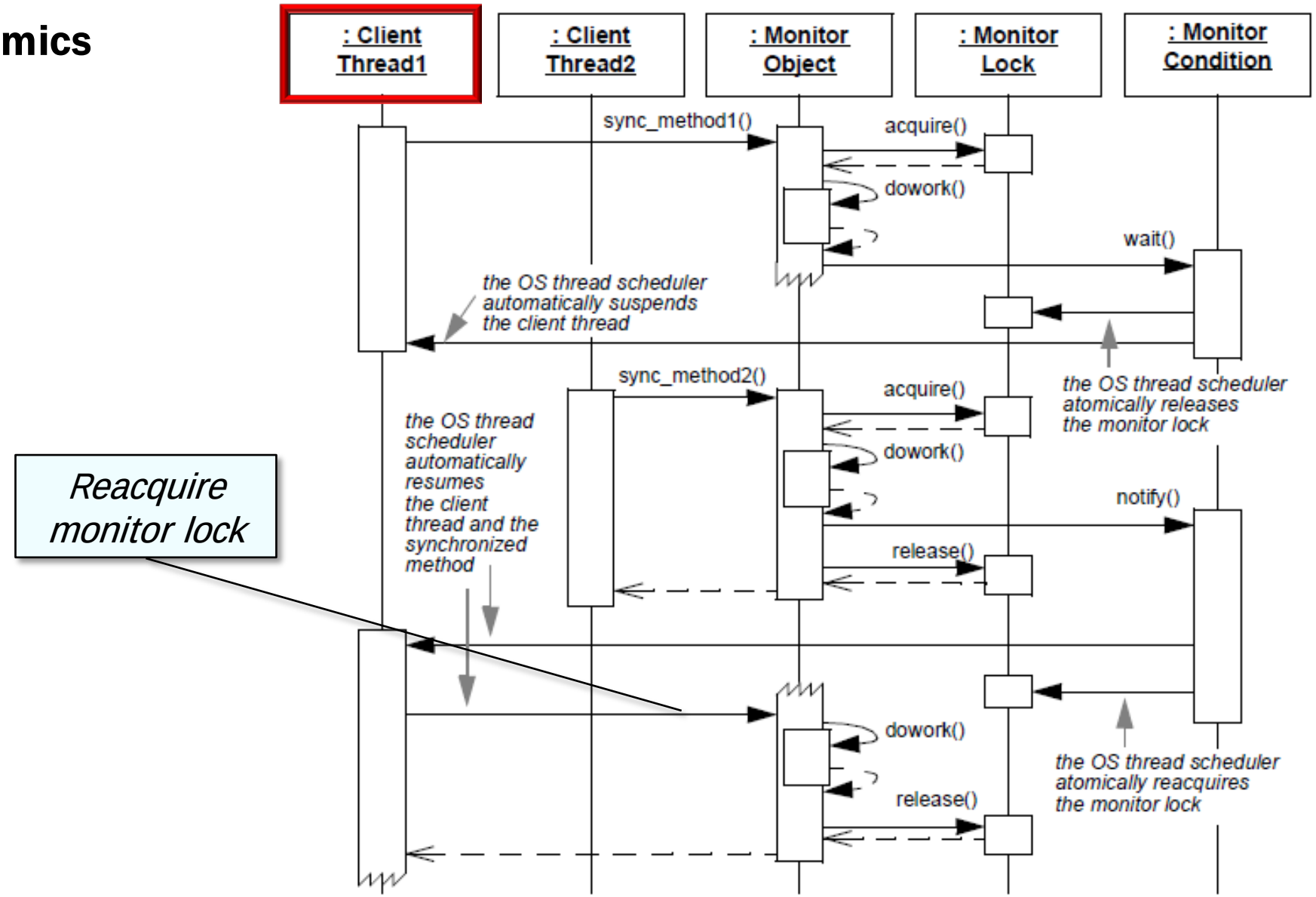

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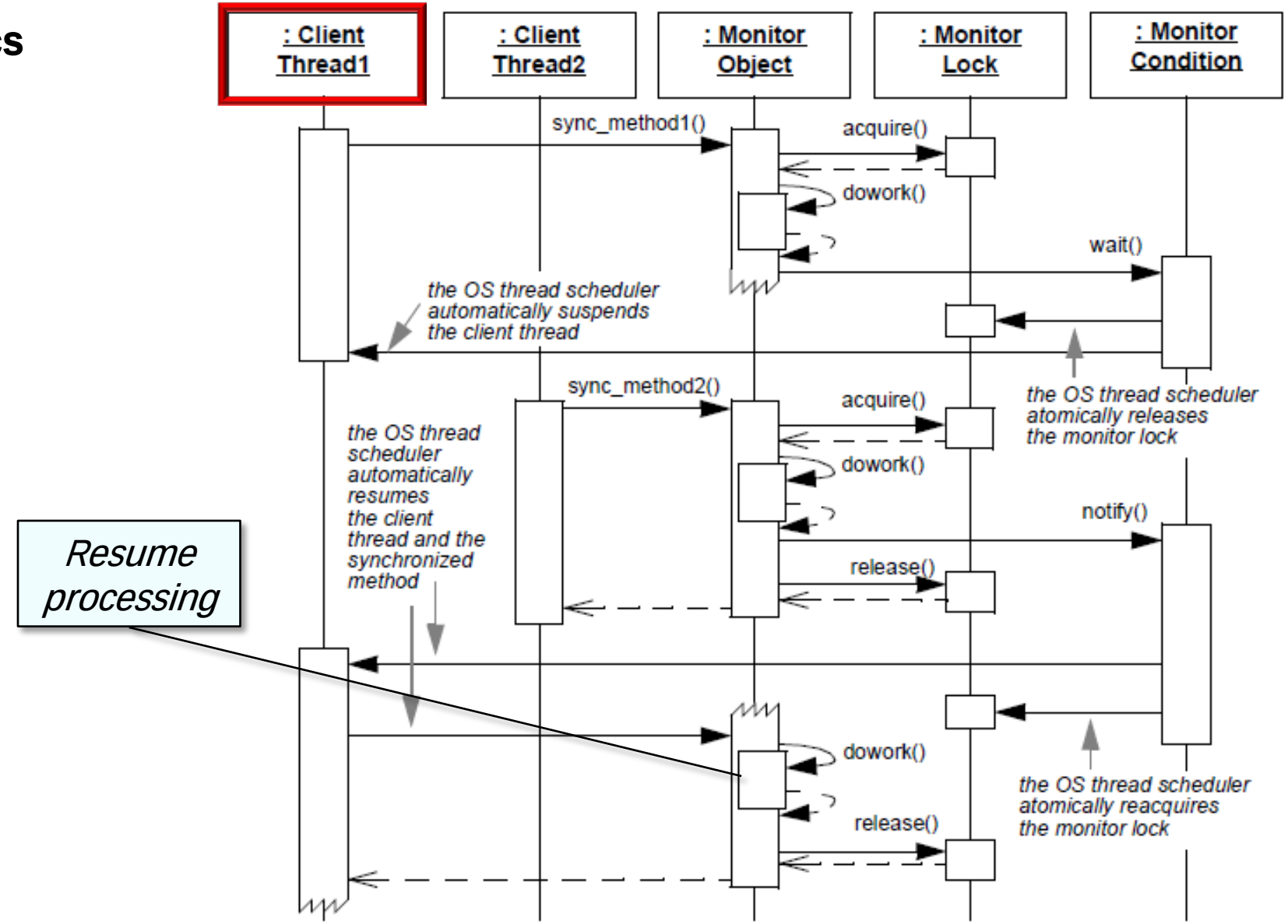


Consequences of the Monitor Object Pattern

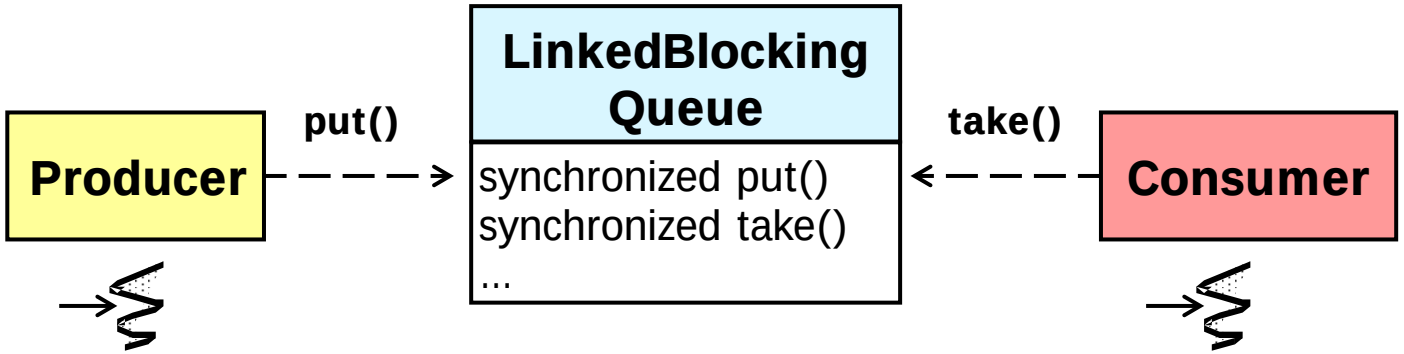
Monitor Object POSA2 Concurrency

Consequences

Monitor Object POSA2 Concurrency

Consequences

+ Concise programming model for concurrency control
  - Simplifies sharing an object among cooperating threads by aligning synchronization transparently with method invocations



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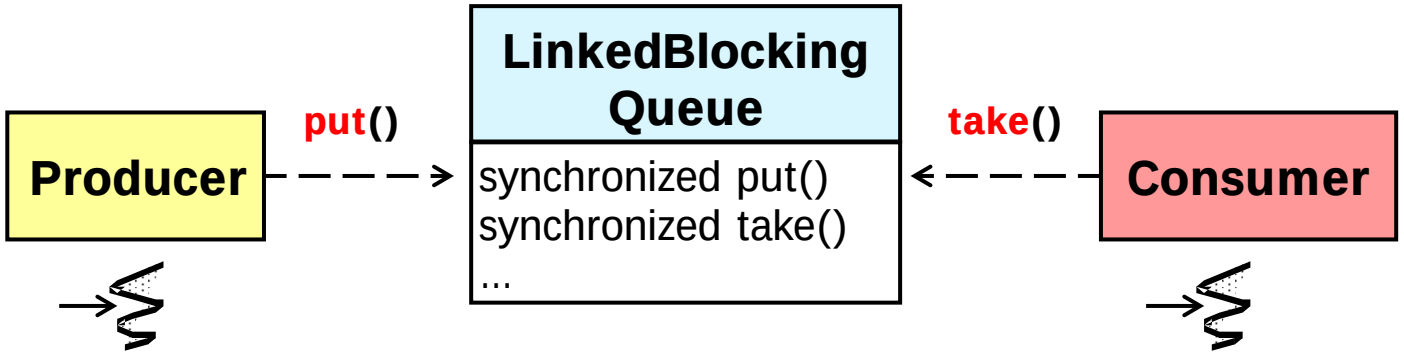

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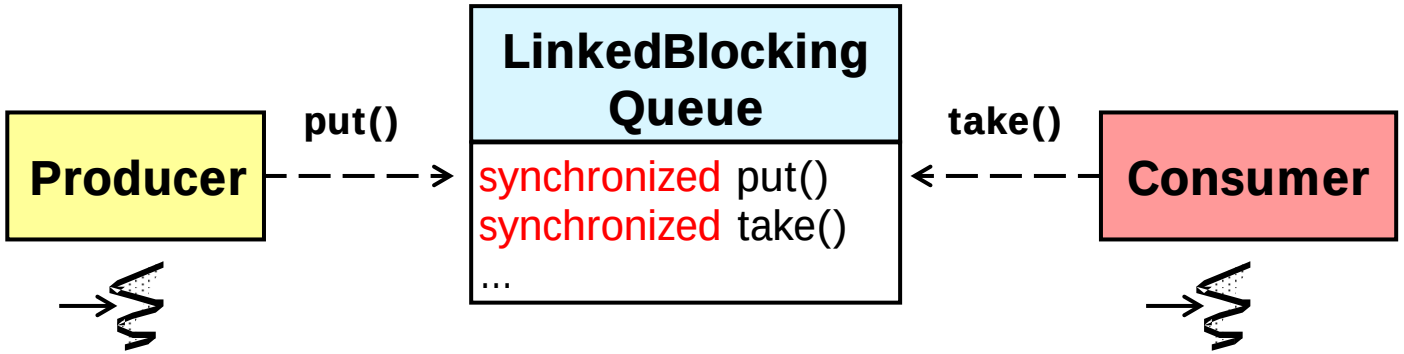


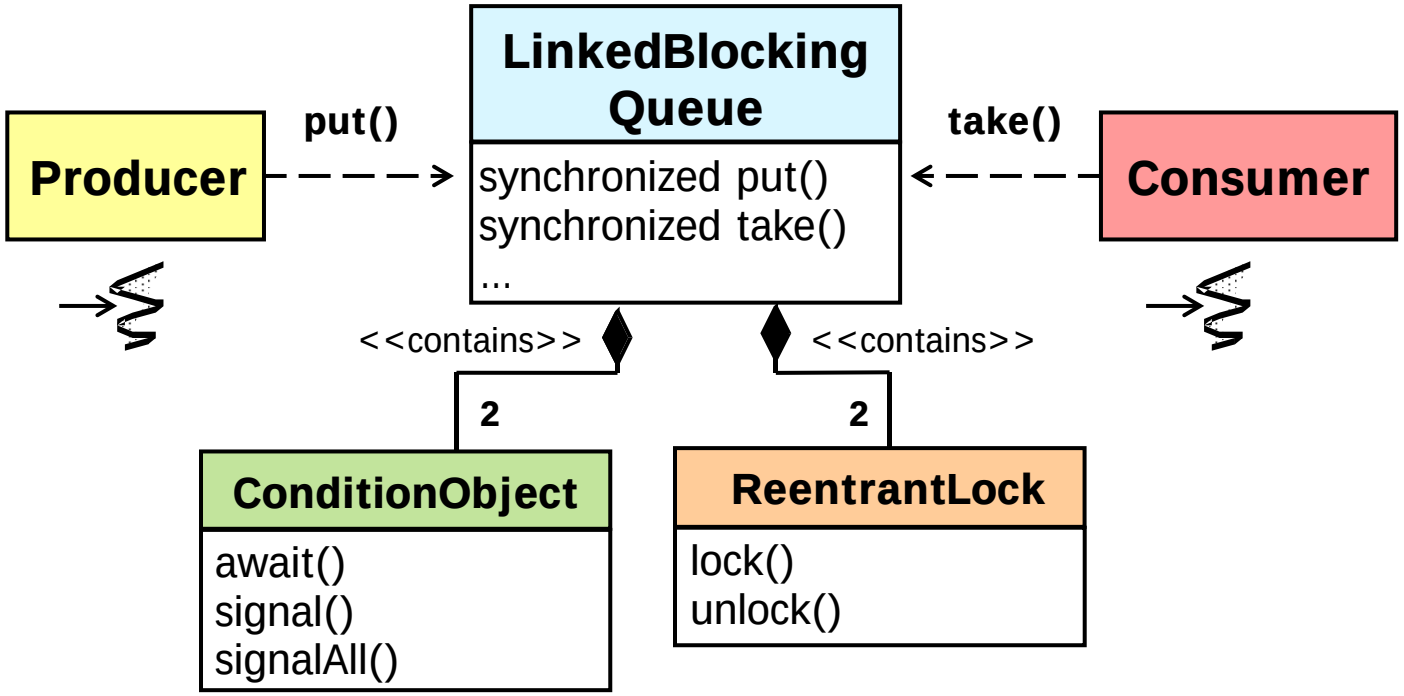
Monitor Object POSA2 Concurrency

Consequences

+ Concise programming model for concurrency control

+ Simplification of scheduling method execution

  - Synchronized methods use monitor conditions to determine when a thread should suspend or resume its execution & that of collaborating threads



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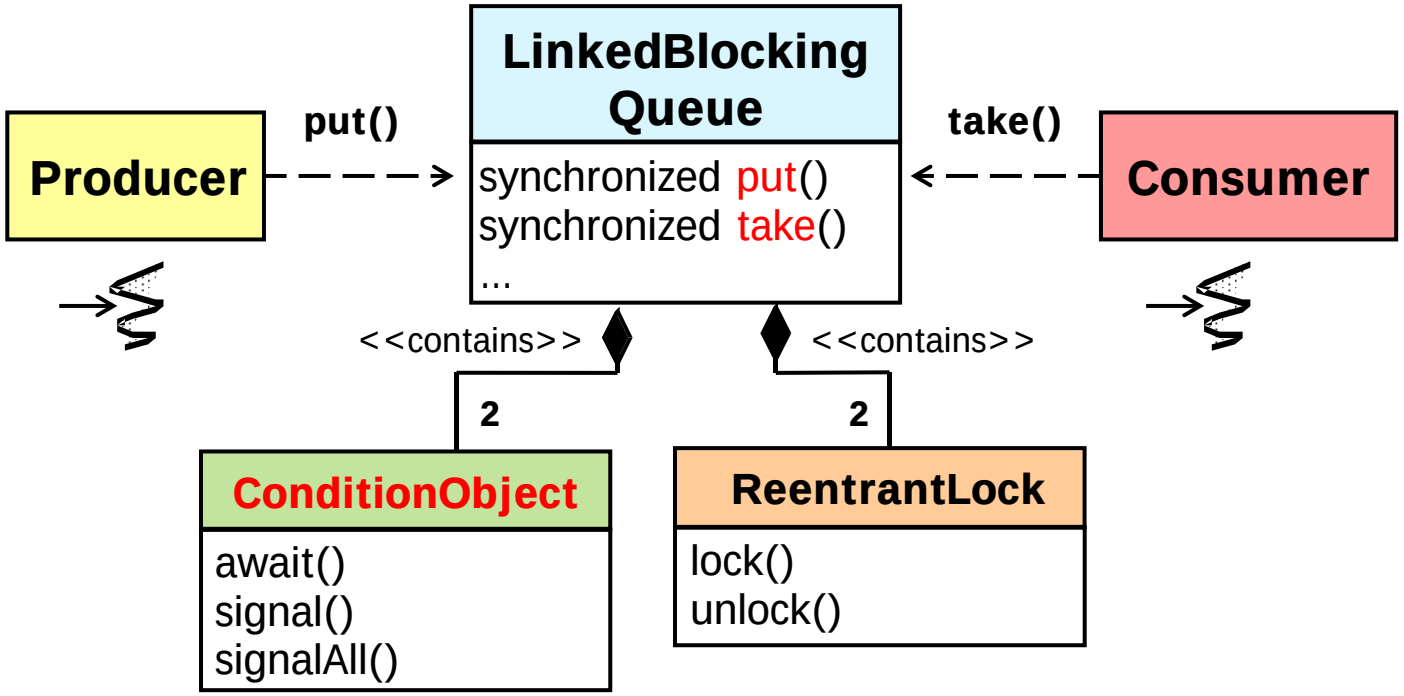


Monitor Object POSA2 Concurrency

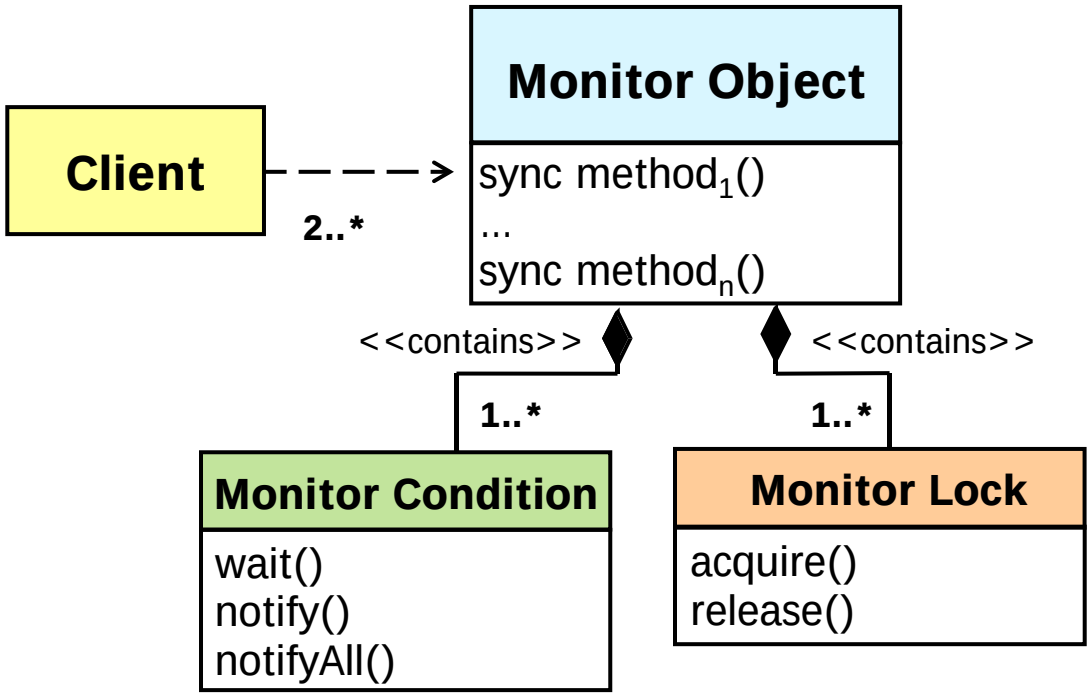
Consequences

Monitor Object POSA2 Concurrency

Consequences

– Limited scalability

- A single monitor lock can limit scalability due to increased contention when multiple threads serialize on a monitor object



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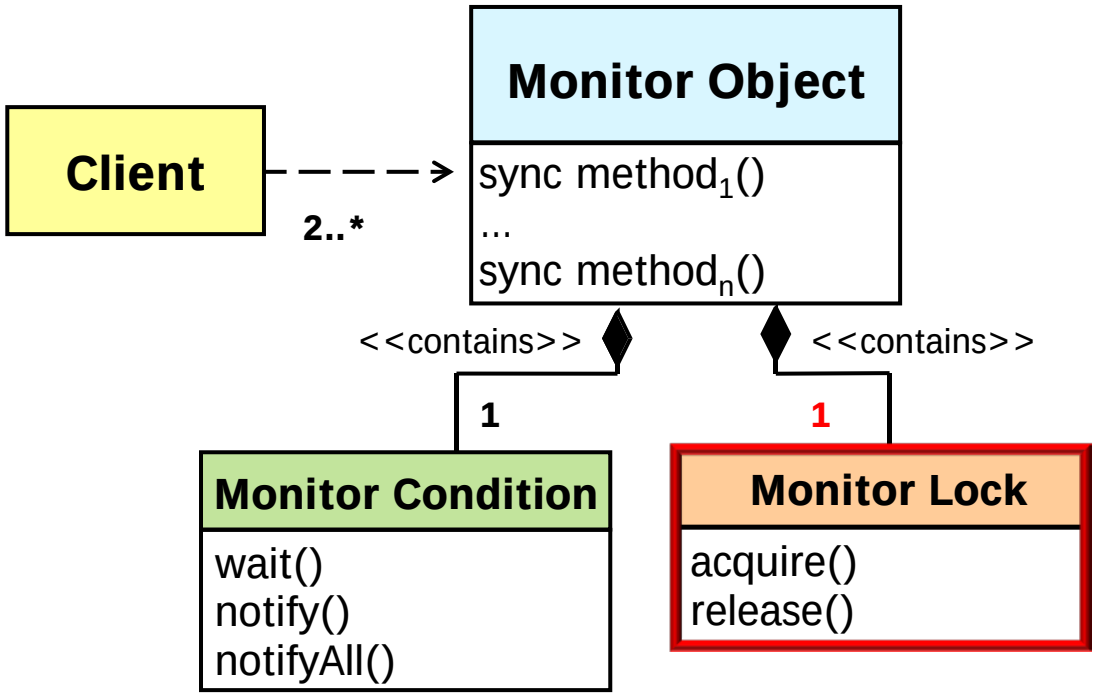

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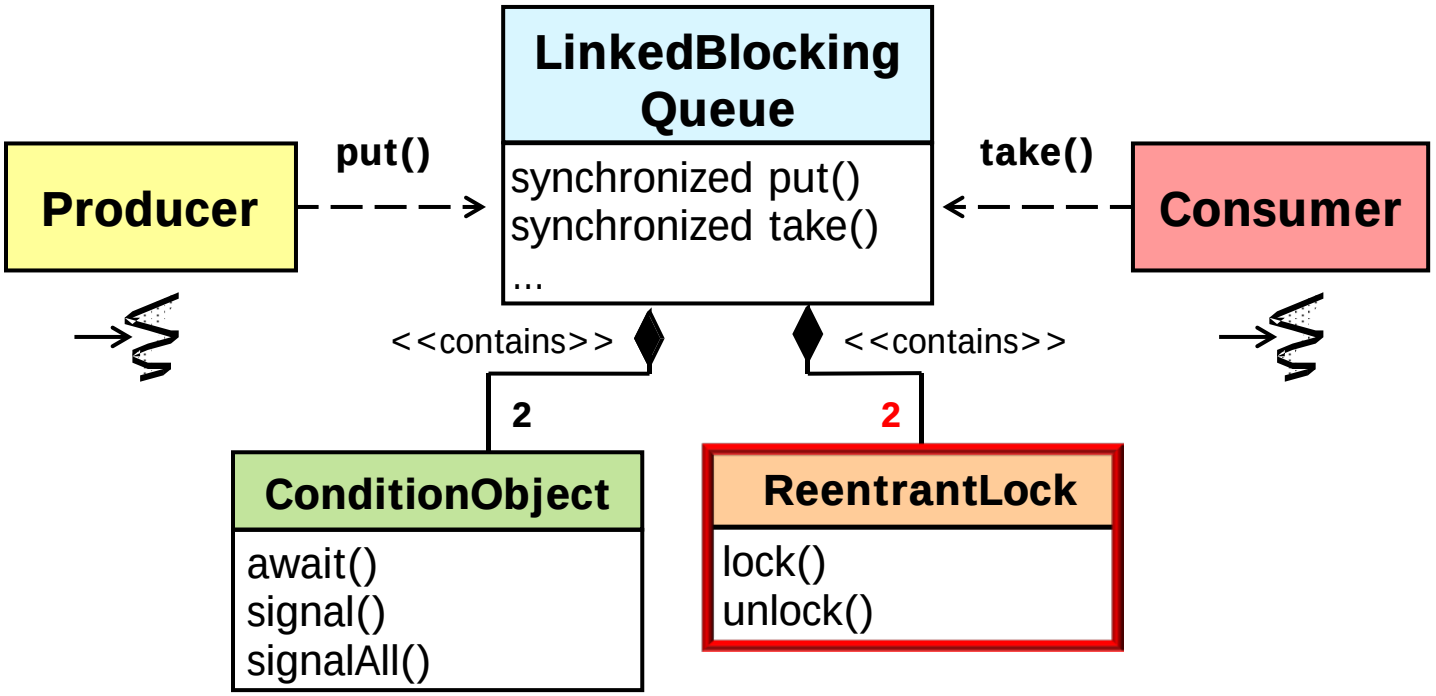

See upcoming part 2 on “The Monitor Object pattern”

Monitor Object POSA2 Concurrency

Consequences

- Limited scalability
- Complicated extensibility semantics
  - Resulting from tight coupling between a monitor object's functionality & its concurrency control mechanisms

```
public class LinkedBlockingQueue<E>
        extends AbstractQueue<E>
        implements BlockingQueue<E>,
        java.io.Serializable {
  public E take() ... {
    ...
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue();
      c = count.getAndDecrement();
      if (c > 1) notEmpty.signal();
    } finally { takeLock.unlock(); }
    if (c == capacity)
      signalNotFull();
    return x;
    ...
```

Monitor Object POSA2 Concurrency

Consequences

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    return x;
    ...
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wisnesky.net/anomaly.pdf has info on the "inheritance anomaly problem"

Known Uses of the Monitor Object Pattern

Monitor Object POSA2 Concurrency

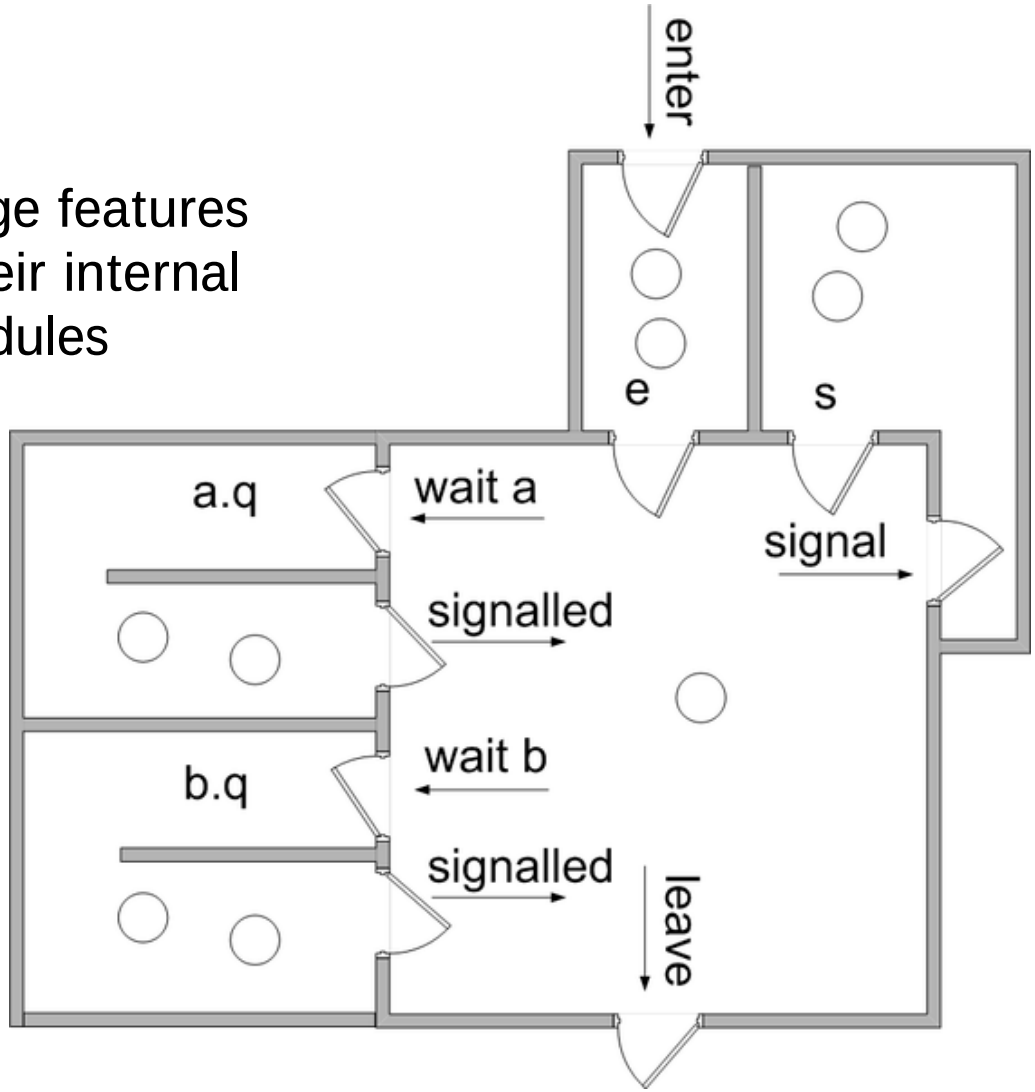
Known Uses

screen.yahoo.com/shimmer-floor-wax-000000185.html has more ;-)

Monitor Object POSA2 Concurrency

Known Uses

- Dijkstra & Hoare-style Monitors
  - Defined programming language features to encapsulate functions & their internal variables into thread-safe modules

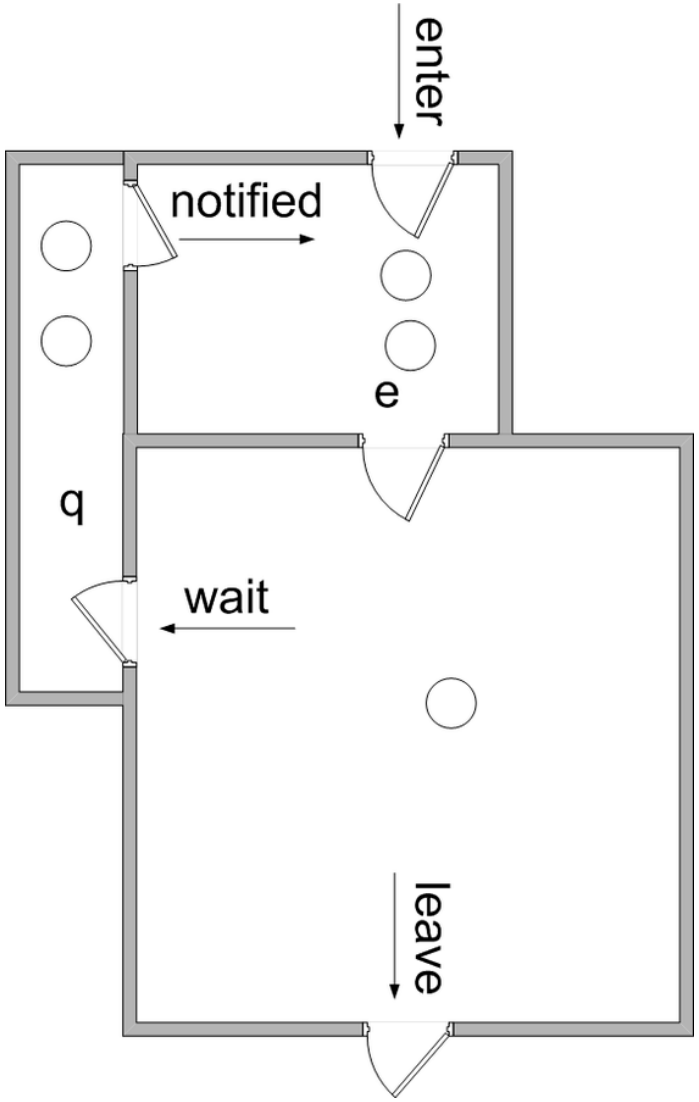


en.wikipedia.org/wiki/Monitor_(synchronization) describes monitors

Monitor Object POSA2 Concurrency

Known Uses

- Dijkstra & Hoare-style Monitors
- Java objects with synchronized methods/blocks



en.wikipedia.org/wiki/Monitor_(synchronization)#Implicit_condition_variable_monitors

Monitor Object POSA2 Concurrency

Known Uses

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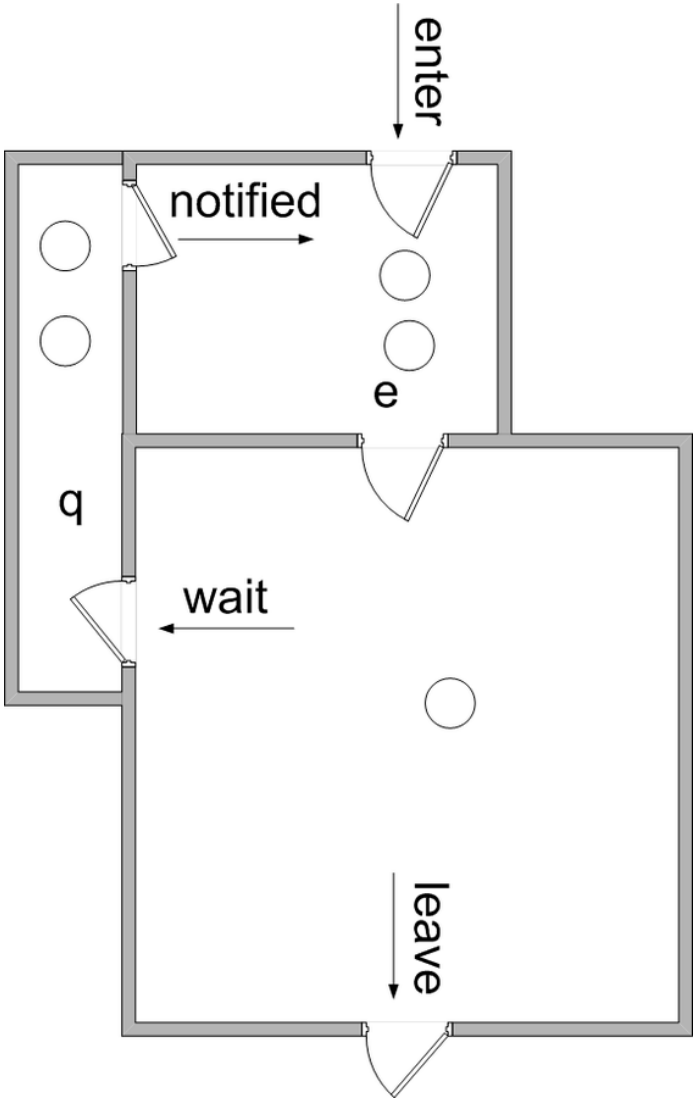
- Java objects with synchronized methods/blocks
  - Any Java object can be used as a monitor object

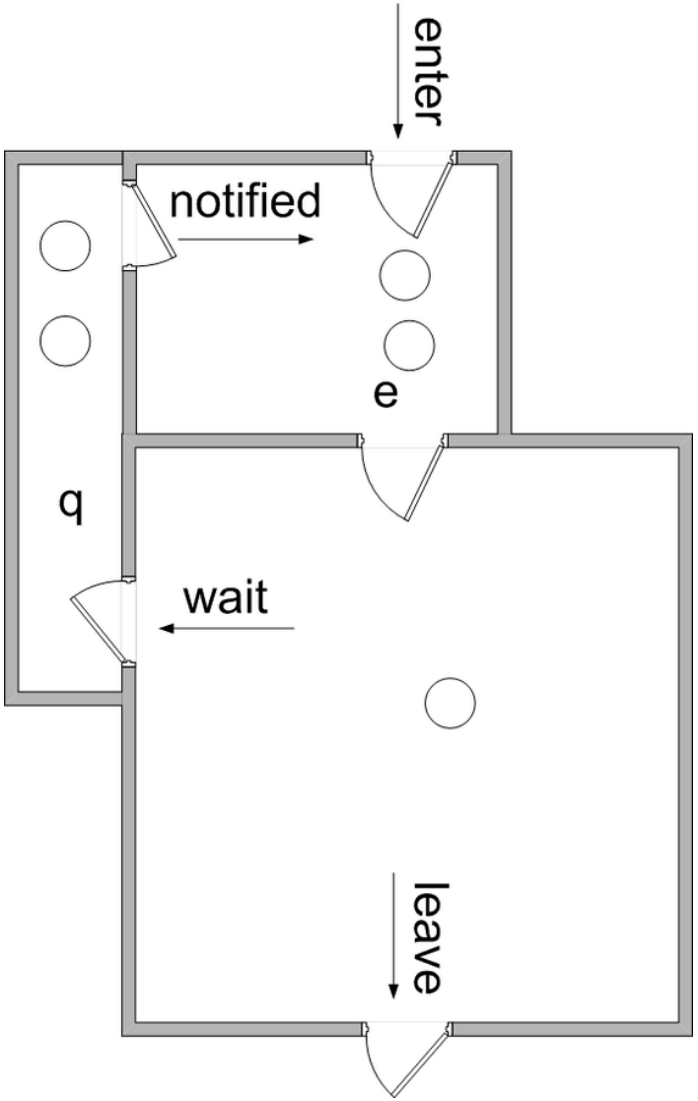


See earlier part on “Java Built-in Monitor Objects”

Monitor Object — POSA2 Concurrency

Known Uses

- Dijkstra & Hoare-style Monitors
- Java objects with synchronized methods/blocks
  - Any Java object can be used as a monitor object
  - Java built-in monitor objects are convenient for simple use cases



Monitor Object POSA2 Concurrency

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- Java objects with synchronized methods/blocks
  - Any Java object can be used as a monitor object
  - Java built-in monitor objects are convenient for simple use cases
  - Although few synchronized methods/blocks are used in java.util.concurrent, the *Monitor Object* pattern is still widely applied

```
public class LinkedBlockingQueue<E>
        extends AbstractQueue<E>
        implements BlockingQueue<E>,
        java.io.Serializable {
  public E take() ... {
    ...
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue();
      c = count.getAndDecrement();
      if (c > 1) notEmpty.signal();
    } finally { takeLock.unlock(); }
    if (c == capacity)
      signalNotFull();
    return x;
    ...
```

Monitor Object — POSA2 Concurrency

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See upcoming part 2 on “The Monitor Object pattern”

Monitor Object POSA2 Concurrency

Known Uses

- Dijkstra & Hoare-style Monitors
- Java objects with synchronized methods/blocks
- C++ libraries provide building blocks for implementing monitor objects, e.g.
  - ACE

ACE Class
ACE_Guard ACE_Read_Guard ACE_Write_Guard
ACE_Thread_Mutex ACE_Process_Mutex ACE_Null_Mutex
ACE_RW_Thread_Mutex ACE_RW_Process_Mutex
ACE_Thread_Semaphore ACE_Process_Semaphore ACE_Null_Semaphore
ACE_Condition_Thread_Mutex ACE_Null_Condition

Monitor Object POSA2 Concurrency

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- Java objects with synchronized methods/blocks
- C++ libraries provide building blocks for implementing monitor objects, e.g.
  - ACE
  - C++11

C++11 threads, locks and condition variables

By **Marius Bancila**, 27 May 2013

★★★★★ 4.92 (34 votes) Rate this: ☆☆☆☆☆

Prize winner in Competition "Best C++ article of May 2013"

Threads

The std::thread class represents a thread of execution and is available in the <thread> header. std::thread can work with regular functions, lambdas and functors (a class implementing operator()). Moreover it allows you to pass any number of parameters to the thread function.

Collapse | Copy Code

```
#include <thread>

void func()
{
   // do some work
}

int main()
{
   std::thread t(func);
   t.join();

   return 0;
}
```

In this example t is a thread object representing the thread under which function func() runs. The call to join blocks the calling thread (in this case the main thread) until the joined thread finishes execution. If the thread function returns a value, it is ignored. However, the function can take any number of parameters.

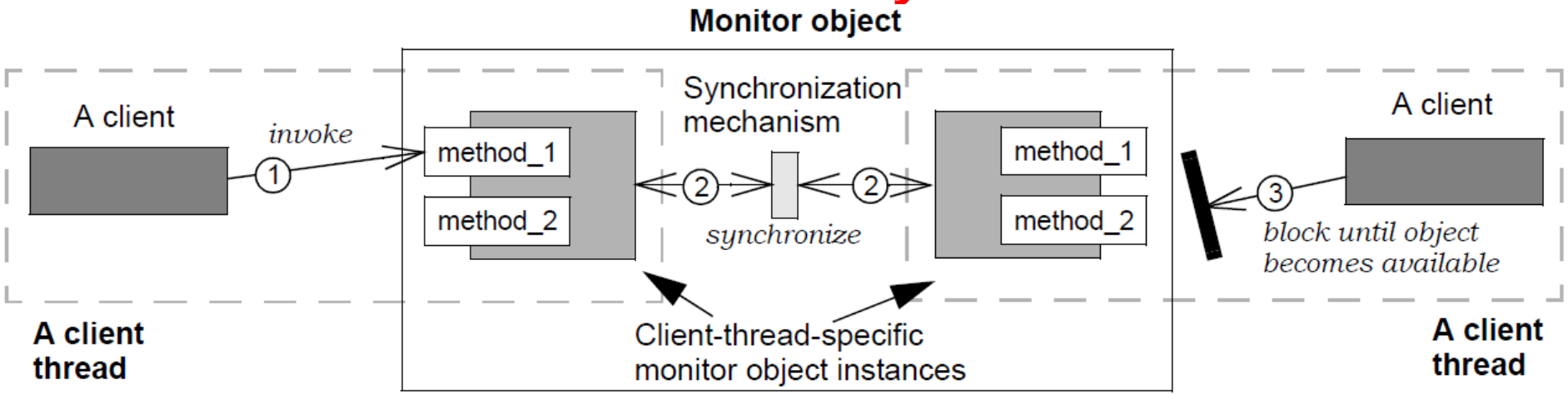
Collapse | Copy Code

```
void func(int i, double d, const std::string& s)
{
    std::cout << i << ", " << d << ", " << s << std::endl;
}

int main()
{
   std::thread t(func, 1, 12.50, "sample");
   t.join();

   return 0;
}
```

www.codeproject.com/Articles/598695/Cplusplus-threads-locks-and-condition-variables

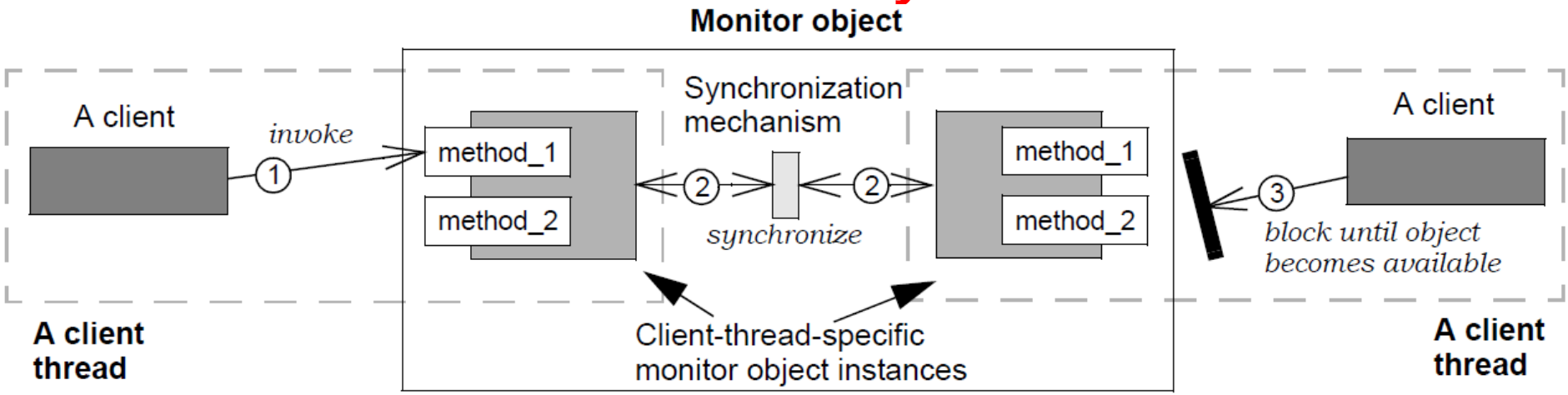
Summary

Summary



- Concurrent software often contains objects whose methods are invoked by multiple client threads

Summary



- Concurrent software often contains objects whose methods are invoked by multiple client threads
  - To protect the internal state of shared objects, it is necessary to synchronize & schedule access to them

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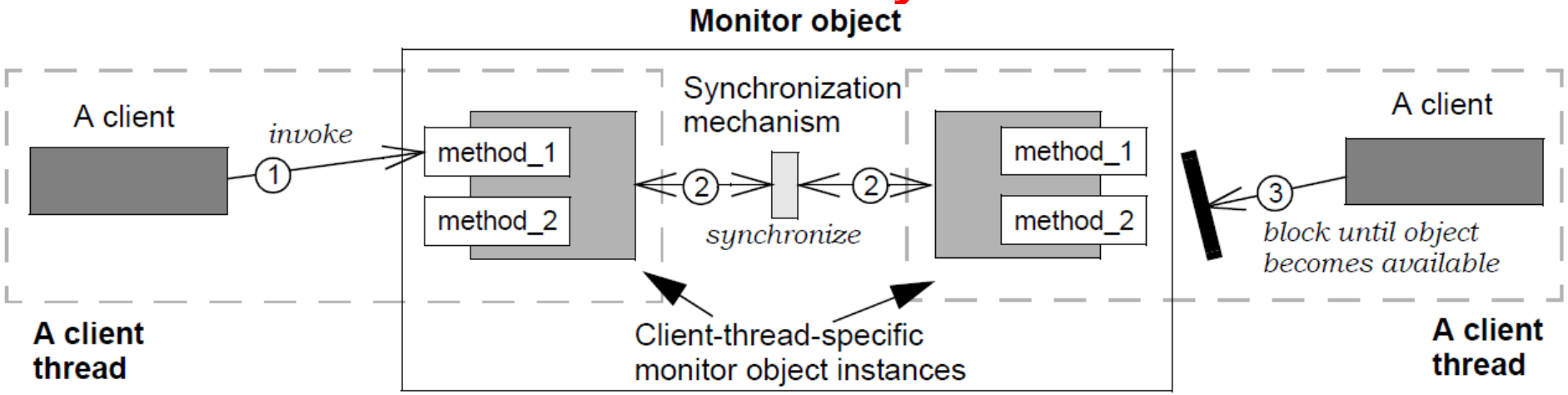
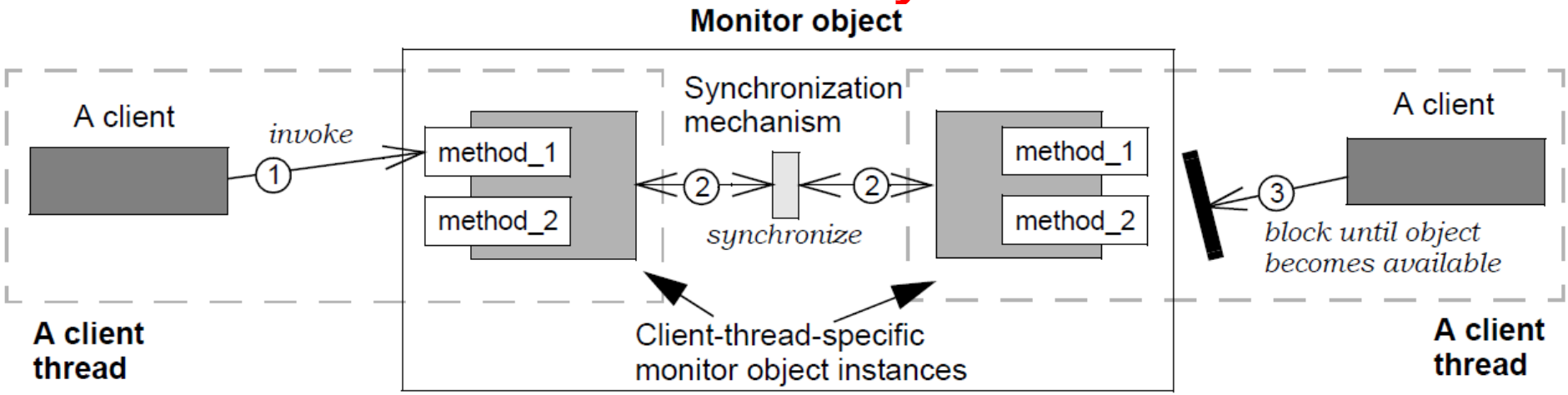


- Concurrent software often contains objects whose methods are invoked by multiple client threads
  - To protect the internal state of shared objects, it is necessary to synchronize & schedule client access to them
  - To simplify programming, however, clients should not need to distinguish between accessing shared & non-shared objects

Summary



- Concurrent software often contains objects whose methods are invoked by multiple client threads
- The *Monitor Object* pattern enables the sharing of object by client threads that cooperate to ensure a serialized—yet interleaved—execution sequence