Learning Objectives in this Part of the Lesson

- Understand the structure & functionality of the Java Phaser barrier synchronizer

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**Class Phaser**

```java
public class Phaser extends Object
```

A reusable synchronization barrier, similar in functionality to **CyclicBarrier** and **CountDownLatch** but supporting more flexible usage.

**Registration.** Unlike the case for other barriers, the number of parties registered to synchronize on a phaser may vary over time. Tasks may be registered at any time (using methods `register()`, `bulkRegister(int)`, or forms of constructors establishing initial numbers of parties), and optionally deregistered upon any arrival (using `arriveAndDeregister()`). As is the case with most basic synchronization constructs, registration and deregistration affect only internal counts; they do not establish any further internal bookkeeping, so tasks cannot query whether they are registered. (However, you can introduce such bookkeeping by subclassing this class.)
Overview of Java Phaser
Overview of Java Phaser

• Implements yet another Java barrier synchronizer

public class Phaser {
  ...

Class Phaser

java.lang.Object
  java.util.concurrent.Phase

public class Phaser
  extends Object

A reusable synchronization barrier, similar in functionality to CyclicBarrier and CountDownLatch but supporting more flexible usage.

Registration. Unlike the case for other barriers, the number of parties registered to synchronize on a phaser may vary over time. Tasks may be registered at any time (using methods register(), bulkRegister(int), or forms of constructors establishing initial numbers of parties), and optionally deregistered upon any arrival (using arriveAndDeregister()). As is the case with most basic synchronization constructs, registration and deregistration affect only internal counts; they do not establish any further internal bookkeeping, so tasks cannot query whether they are registered. (However, you can introduce such bookkeeping by subclassing this class.)

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/Phaser.html
Overview of Java Phaser

- Implements yet another Java barrier synchronizer
- Allows a variable (or fixed) # of threads to wait for all operations performed in other threads to complete before proceeding

Class Phaser

```java
public class Phaser {
    ...
}
```

One human known use is different work-crews with different #'s of workers coordinating to build a house.
Overview of Java Phaser

- Implements yet another Java barrier synchronizer
- Allows a variable (or fixed) # of threads to wait for all operations performed in other threads to complete before proceeding
- Well-suited for variable-size “cyclic”, “entry”, and/or “exit” barriers

```java
public class Phaser {
    ...
}
```

---

**Class Phaser**

defined in java.lang;
extends Object

A reusable synchronization barrier, similar in functionality to CyclicBarrier and CountDownLatch but supporting more flexible usage.

**Registration.** Unlike the case for other barriers, the number of parties registered to synchronize on a phaser may vary over time. Tasks may be registered at any time (using methods register(), bulkRegister(int), or forms of constructors establishing initial numbers of parties), and optionally deregistered upon any arrival (using arriveAndDeregister()). As is the case with most basic synchronization constructs, registration and deregistration affect only internal counts; they do not establish any further internal bookkeeping, so tasks cannot query whether they are registered. (However, you can introduce such bookkeeping by subclassing this class.)
Overview of Java Phaser

- Implements yet another Java barrier synchronizer
- Allows a variable (or fixed) # of threads to wait for all operations performed in other threads to complete before proceeding
- Well-suited for variable-size “cyclic”, “entry”, and/or “exit” barriers
- # of parties can vary dynamically

Class Phaser

java.lang.Object
java.util.concurrent.Phase

A reusable synchronization barrier, similar in functionality to CyclicBarrier and CountDownLatch but supporting more flexible usage.

**Registration.** Unlike the case for other barriers, the number of parties *registered* to synchronize on a phaser may vary over time. Tasks may be registered at any time (using methods `register()`, `bulkRegister(int)`, or forms of constructors establishing initial numbers of parties), and optionally deregistered upon any arrival (using `arriveAndDeregister()`). As is the case with most basic synchronization constructs, registration and deregistration affect only internal counts; they do not establish any further internal bookkeeping, so tasks cannot query whether they are registered. (However, you can introduce such bookkeeping by subclassing this class.)

A Phaser may be overkill for fixed-sized barriers.
Overview of Java Phaser

- Implements yet another Java barrier synchronizer
- Allows a variable (or fixed) # of threads to wait for all operations performed in other threads to complete before proceeding
- Well-suited for variable-size “cyclic”, “entry”, and/or “exit” barriers
- # of parties can vary dynamically

```
public class Phaser {
    ...

Does not implement an interface
```

Class Phaser

java.lang.Object
    java.util.concurrent.Phase

public class Phaser
extends Object

A reusable synchronization barrier, similar in functionality to CyclicBarrier and CountDownLatch but supporting more flexible usage.

Registration. Unlike the case for other barriers, the number of parties registered to synchronize on a phaser may vary over time. Tasks may be registered at any time (using methods register(), bulkRegister(int), or forms of constructors establishing initial numbers of parties), and optionally deregistered upon any arrival (using arriveAndDeregister()). As is the case with most basic synchronization constructs, registration and deregistration affect only internal counts; they do not establish any further internal bookkeeping, so tasks cannot query whether they are registered. (However, you can introduce such bookkeeping by subclassing this class.)
Overview of Java Phaser

- Does not apply *Bridge* pattern

```
public class Phaser {
  ...
```

See `share/classes/java/util/concurrent/Phaser.java`
Overview of Java Phaser

• Does not apply *Bridge* pattern
• Nor does it use the Abstract QueuedSynchronizer framework

```java
public class Phaser {
    ...
}
```

[Diagram showing the relationship between Phaser, AbstractQueuedSynchronizer, Sync, and NonFairSync classes.]
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser

```java
public class Phaser {
    private volatile long state;
    ...
}
```

See `src/share/classes/java/util/concurrent/Phaser.java`
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser

• Primary state representation, holding four bit-fields

```java
class Phaser {
    private volatile long state;
}
```

See [en.wikipedia.org/wiki/Bit_field](http://en.wikipedia.org/wiki/Bit_field)
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser

• Primary state representation, holding four bit-fields:
  • Unarrived
    • the # of parties yet to hit barrier (bits 0-15)

public class Phaser {
    private volatile long state;
}
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser

  • Primary state representation, holding four bit-fields:
    • Unarrived
    • Parties
      • the # of parties to wait for before advancing to the next phase (bits 16-31)

public class Phaser {
    private volatile long state;
}
• Instead, it defines a # of fields that implement a phaser

• Primary state representation, holding four bit-fields:
  • Unarrived
  • Parties
  • Phase
    • the generation of the barrier (bits 32-62)
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser

• Primary state representation, holding four bit-fields:
  • Unarrived
  • Parties
  • Phase
  • Terminated
    • set if barrier is terminated (bit 63 / sign)

```java
public class Phaser {
    private volatile long state;
}
```
Overview of Java Phaser

• Instead, it defines a # of fields that implement a phaser
  • Primary state representation, holding four bit-fields:
    • **Unarrived**
      • the # of parties yet to hit barrier (bits 0-15)
    • **Parties**
      • the # of parties to wait (bits 16-31)
    • **Phase**
      • the generation of the barrier (bits 32-62)
    • **Terminated**
      • set if barrier is terminated (bit 63 / sign)

```java
public class Phaser {
    private volatile long state;
}
```

To efficiently maintain atomicity, these values are packed into a single (atomic) long that is updated via CAS operations.
End of Java Phaser: Structure & Functionality
1. What of the following are benefit of the Java Phaser over the CyclicBarrier?
   
   a. *It supports fixed-size “cyclic” & “entry” and/or “exit” barriers who # of parties match the # of threads*
   
   b. *It supports variable-size “cyclic” & “entry” and/or “exit” barriers whose # of parties can vary dynamically*
   
   c. *It uses the AbstractQueuedSynchronizer framework to enhance reuse*
   
   d. *They provide better support for fixed-sized # of parties*
Java Phaser:
Key Methods

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Learning Objectives in this Part of the Lesson

- Understand the structure & functionality of the Java Phaser barrier synchronizer
- Recognize the key methods in the Java Phaser

```
<<Java Class>>
Phaser

- Phaser()
- Phaser(int)
- Phaser(Phaser)
- Phaser(Phaser, int)
- register(): int
- bulkRegister(int): int
- arrive(): int
- arriveAndDeregister(): int
- arriveAndAwaitAdvance(): int
- awaitAdvance(int): int
- awaitAdvanceInterruptibly(int): int
- awaitAdvanceInterruptibly(int, long, TimeUnit): int
- forceTermination(): void
- getPhase(): int
- getRegisteredParties(): int
- getArrivedParties(): int
- getUnarrivedParties(): int
- getParent(): Phaser
- getRoot(): Phaser
- isTerminated(): boolean
- onAdvance(int, int): boolean
- toString()
```
Key Methods in Java Phaser
Key Methods in Java Phaser

• Constructor creates a new object with an initial phase # of 0

```java
public class Phaser {
    ...
    public Phaser() { ... }

    public Phaser(int parties) {
        ...
    }
}
```
Key Methods in Java Phaser

- Constructor creates a new object with an initial phase # of 0
- Any thread using this Phaser needs to register for it first

```java
public class Phaser {
    ...
    public Phaser() {
        ...
    }
    public Phaser(int parties) {
        ...
    }
}```
Key Methods in Java Phaser

- Constructor creates a new object with an initial phase # of 0
- Any thread using this Phaser needs to register for it first
- Can also specify the # of parties needed to advance to next phase

```java
public class Phaser {
    ...
    public Phaser() { ... }
    public Phaser(int parties) {
        ...
    }
}
```
Key Methods in Java Phaser

- Constructor creates a new object with an initial phase # of 0
- Any thread using this Phaser needs to register for it first
- Can also specify the # of parties needed to advance to next phase
- However, using this constructor is optional since parties can always register later

```java
public class Phaser {
    ... 
    public Phaser() {
        ... 
    }
    public Phaser(int parties) {
        ...
    }
}
```
Phaser’s key methods enable parties to register, synchronize, & terminate

```java
public class Phaser {
    ...  
    public int register() { ... }

    public int bulkRegister((int parties) { ... }

    public int arriveAndAwaitAdvance() {
        ... }

    public int ArriveAndDeregister() {
        ... }

    protected boolean onAdvance(int phase, int registeredParties) {
        return registeredParties == 0;
    }
}
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
- Adds unarrived parties to phaser

```java
public class Phaser {
    ...
    public int register() { ... }
    public int bulkRegister (int parties) { ... }
}

# of registered parties dictates when a phaser can advance
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
  - Arrive & await advance

```java
public class Phaser {
    ...
    public int arrive() { ... }
    public int awaitAdvance(int phase) {
        ... }
    public int arriveAndAwaitAdvance() {
        ... }
}
```

These methods provide flexibility wrt arrival & waiting to advance
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
  - Arrive & await advance
    - Arrives at phaser without waiting for others to arrive

```java
public class Phaser {
  ...
  public int arrive() { ... }

  public int awaitAdvance(int phase) {
    ... }

  public int arriveAndAwaitAdvance() {
    ... }
```
Phaser’s key methods enable parties to register, synchronize, & terminate

• Adds unarrived parties to phaser
• Arrive & await advance
  • Arrives at phaser without waiting for others to arrive
  • Returns arrival phase #

```java
public class Phaser {
    ...
    public int arrive() { ... }

    public int awaitAdvance(int phase)
    { ... }

    public int arriveAndAwaitAdvance()
    { ... }
}
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
- Arrive & await advance
  - Arrives at phaser without waiting for others to arrive
  - Returns arrival phase #
  - Or negative value if phaser terminated

```java
class Phaser {
    public int arrive() { ... }
    public int awaitAdvance(int phase) { ... }
    public int arriveAndAwaitAdvance() { ... }
}
```
Phaser’s key methods enable parties to register, synchronize, & terminate

- Adds unarrived parties to phaser
- Arrive & await advance
  - Arrives at phaser without waiting for others to arrive
  - Awaits the phase of this phaser to advance from the given phase value

```java
public class Phaser {
    ...
    public int arrive() { ... }

    public int awaitAdvance(int phase) {
        ... }

    public int arriveAndAwaitAdvance() {
        ... }
```
Phaser’s key methods enable parties to register, synchronize, & terminate

- Adds unarrived parties to phaser
- Arrive & await advance
  - Arrives at phaser without waiting for others to arrive
  - Awaits the phase of this phaser to advance from the given phase value
    - Returns immediately if current phase != given phase

```java
public class Phaser {
    ...
    public int arrive() { ... }

    public int awaitAdvance(int phase) {
        ... }

    public int arriveAndAwaitAdvance() {
        ... }
```
Phaser’s key methods enable parties to register, synchronize, & terminate

• Adds unarrived parties to phaser
• Arrive & await advance
  • Arrives at phaser without waiting for others to arrive
  • Awaits the phase of this phaser to advance from the given phase value
• Arrives at phaser & awaits the arrival of others

```
public class Phaser {
    ...
    public int arrive() { ... }
    
    public int awaitAdvance(
        int phase
    )
    {
        ...
    }
    
    public int
        arriveAndAwaitAdvance()
    {
        ...
    }

    // Equivalent in effect to awaitAdvance(arrive())
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
  - Arrive & await advance
  - Arrive at the phaser & deregister without waiting for others to arrive

```java
public class Phaser {
    ...
    public int arriveAndDeregister()
    { ... }
}
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
  - Arrive & await advance
  - Arrive at the phaser & deregister without waiting for others to arrive
    - Reduces # of parties required to advance in future phases

```java
public class Phaser {
    ...
    public int arriveAndDeregister()
    {
        ...
    }
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
- Adds unarrived parties to phaser
- Arrive & await advance
- Arrive at the phaser & deregister without waiting for others to arrive
- Hook method performs an action upon pending phase advance

```java
public class Phaser {
    ...
    protected boolean onAdvance (int phase,
                                  int registeredParties) {
        return registeredParties == 0;
    }
}
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
- Adds unarrived parties to phaser
- Arrive & await advance
- Arrive at the phaser & deregister without waiting for others to arrive
- Hook method performs an action upon pending phase advance
- Also initiates termination by returning true

```java
public class Phaser {
    ...
    protected boolean onAdvance(int phase, int registeredParties) {
        return registeredParties == 0;
    }
}
```
Key Methods in Java Phaser

- Phaser’s key methods enable parties to register, synchronize, & terminate
  - Adds unarrived parties to phaser
  - Arrive & await advance
  - Arrive at the phaser & deregister without waiting for others to arrive
  - Hook method performs an action upon pending phase advance
  - Also initiates termination by returning true

```java
public class Phaser {
    ...
    protected boolean onAdvance(
        int phase,
        int registeredParties) {
        return registeredParties == 0;
    }
}
```

*Default implementation terminates if there are no registered parties*
End of Java Phaser: Key Methods
1. What of the following are benefit of the Java Phaser over the CyclicBarrier?

a. It supports fixed-size “cyclic” & “entry” and/or “exit” barriers who # of parties match the # of threads

b. It supports variable-size “cyclic” & “entry” and/or “exit” barriers whose # of parties can vary dynamically

c. It uses the AbstractQueuedSynchronizer framework to enhance reuse

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