

# ***Distributed Systems***

## **4. Programming with Threads**

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# Processes vs. Threads

Components of distributed systems have to do different things at the same time (concurrency)

Realization by **processes** is **expensive**

- processes have separate resources (e.g., memory space)
- ➔ switching between processes keeps the kernel busy

**Threads** are **cheaper**

- run in **one process** (each process has at least one)
- **share** memory space and other resources  
(which gives rise to other difficulties)

# Threads in Java


- Threads are first class objects
  - instances of the class `Thread` —  
or of a subclass of `Thread`, created by the programmer
- In every program, there is a thread “main”
- The class `Thread` implements the interface `Runnable`
  - `Runnable` has only one method: `run()`
- Threads can be constructed from implementations of `Runnable`, using constructors, like
  - `new Thread(Runnable target)`
  - `new Thread(Runnable target, String name)`

# Threads in Java (cntd)

- Threads have the following **methods**
  - `run()`
  - `start()`
  - `getPriority()`
  - `join()` *(waits for the thread to die)*
- The class `Thread` has also **static methods**, e.g.,
  - `yield()` *(lets the current thread pause)*
  - `sleep(long n)` *(lets the current thread pause for n milliseconds)*
- Threads can be **daemons** and may belong to **groups**

# Extending the Class Thread (Example)

```
class PrimeThread extends Thread {  
  
    long minPrime;  
  
    PrimeThread(long minPrime) {  
        this.minPrime = minPrime;  
    }  
  
    public void run() {  
        // compute primes larger than minPrime  
        . . .  
    }  
}
```

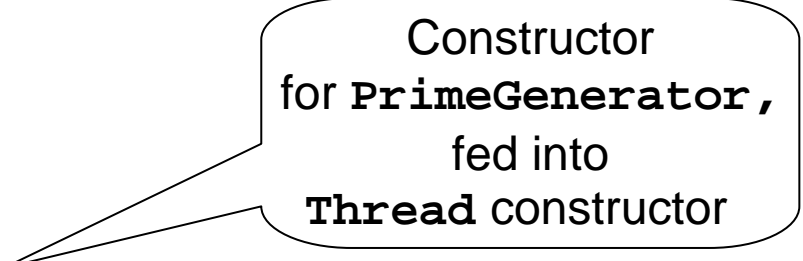


Constructor  
for PrimeThread

# Constructing a Thread from a “Runnable”

```
class PrimeGenerator implements Runnable {
    long minPrime;
    PrimeGenerator(long minPrime) {
        this.minPrime = minPrime;
    }

    public void run() {
        // compute primes larger than minPrime
        . . .
    }
}
```



Constructor  
for PrimeGenerator,  
fed into  
Thread constructor

```
Thread primeThread =
    new Thread(new PrimeGenerator(1000));

primeThread.start();
```

*Is this better? If so, why?*

# Putting a Thread Asleep

## Static methods

`Thread.sleep(ms)`

`Thread.sleep(ms, ns)`

- Current **thread pauses** for (approx.) the indicated time
- Useful for
  - making processor time available for other threads
  - ensuring that thread proceeds with a defined rhythm  
*(“pacing” a thread)*

# Thread Interference

```
public class Counter {  
    int c = 0;  
  
    public void increment() { c++; }  
  
    public void decrement() { c--; }  
  
    public int value() { return c; }  
}
```

- In reality, `increment()` and `decrement()` are **complex operations**
- Two threads A, B may **interfere** when accessing the same counter
- Aim: B must see the effect of A's action (or vice versa)
  - ➔ A **“happens before”** B



# Synchronisation

Achieves “happens before” relationship  
between threads accessing an object

## Principles:

- Every object has an **intrinsic lock** (= “monitor”)
- A **lock** for on object is acquired e.g., by executing
  - a **synchronised method** of that object, or
  - a **synchronized statement** for that object (*see below*)
- **Methods** can be declared as synchronized
  - e.g., `public synchronized void updateBalance(..)`  
for class `Account`
  - `acc.updateBalance(...)` can only be executed by a thread  
if the thread has a lock for `acc`
  - when the method call is completed, the lock is released

# Example: A Synchronized Counter

```
public class SynchronizedCounter {
    int c = 0;

    public synchronized void increment() {
        c++;
    }

    public synchronized void decrement() {
        c--;
    }

    public synchronized int value() {
        return c;
    }
}
```

# Synchronization Wrappers for Collections

Collections (Set, List, Map, SortedSet, and SortedMap)

are typical data structures to be shared by several threads

→ need for synchronization

- Factory methods of class Collections can make a collection object “thread safe”

```
List msgQueue =  
    Collections.synchronizedList(new LinkedList());
```

- Iteration has to be synchronized by a **synchronized statement**

```
synchronized(msgQueue) {  
    Iterator i = msgQueue.iterator();  
        // must be in synchronized block  
    while (i.hasNext())  
        send(i.next());  
}
```

# Deadlocks

Scenario: two threads  $T_1$ ,  $T_2$

- $T_1$  has a lock for object  $O_1$ ,  $T_2$  has a lock for object  $O_2$
- $T_1$  needs a lock for  $O_2$  to complete work on  $O_1$ ,  
 $T_2$  needs a lock for  $O_1$  to complete work on  $O_2$

→ Deadlock

# References

In preparing the lectures I have used several sources.  
The main one is the following:

Web:

- The Java tutorials, Lesson Concurrency

<http://java.sun.com/docs/books/tutorial/essential/concurrency/index.html>