

Introduction

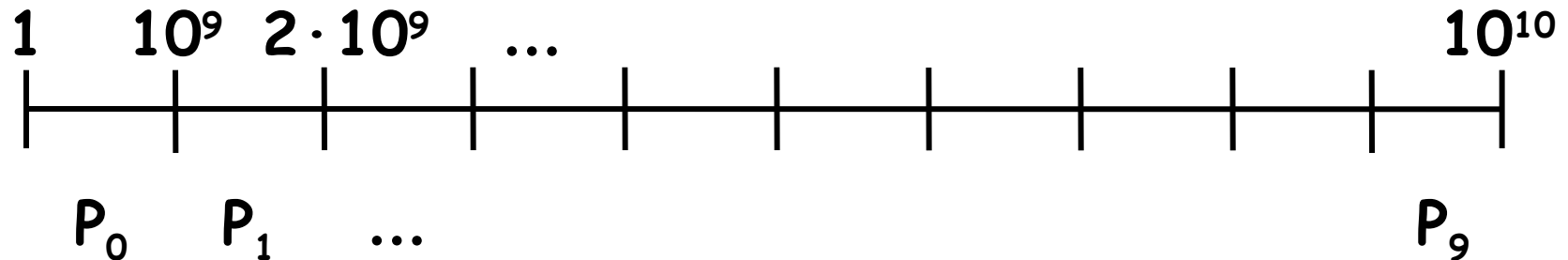
Companion slides for
The Art of Multiprocessor
Programming
by Maurice Herlihy & Nir Shavit

(Abridged version. Original at <http://booksite.elsevier.com/9780123705914/?ISBN=9780123705914>)

Parallel Primality Testing

- Challenge
 - Print primes from 1 to 10^{10}
- Given
 - Ten-processor multiprocessor
 - One thread per processor
- Goal
 - Get ten-fold speedup (or close)

Load Balancing



- Split the work evenly
- Each thread tests range of 10^9

Procedure for Thread i

```
void primePrint {  
    int i = ThreadID.get(); // IDs in {0..9}  
    for (j = i*109+1, j<(i+1)*109; j++) {  
        if (isPrime(j))  
            print(j);  
    }  
}
```

Issues

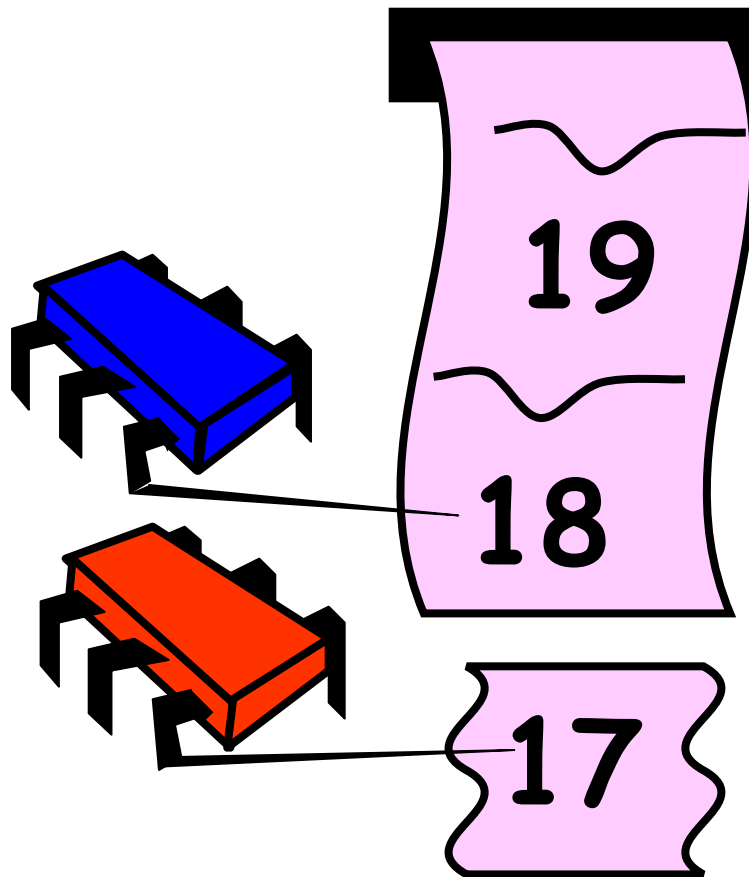
- Higher ranges have fewer primes
- Yet larger numbers harder to test
- Thread workloads
 - Uneven
 - Hard to predict

Issues

- Higher ranges have fewer primes
- Yet larger numbers harder to test
- Thread workloads
 - Uneven
 - Hard to predict
- Need *dynamic* load balancing

rejected

Shared Counter



each thread
takes a
number

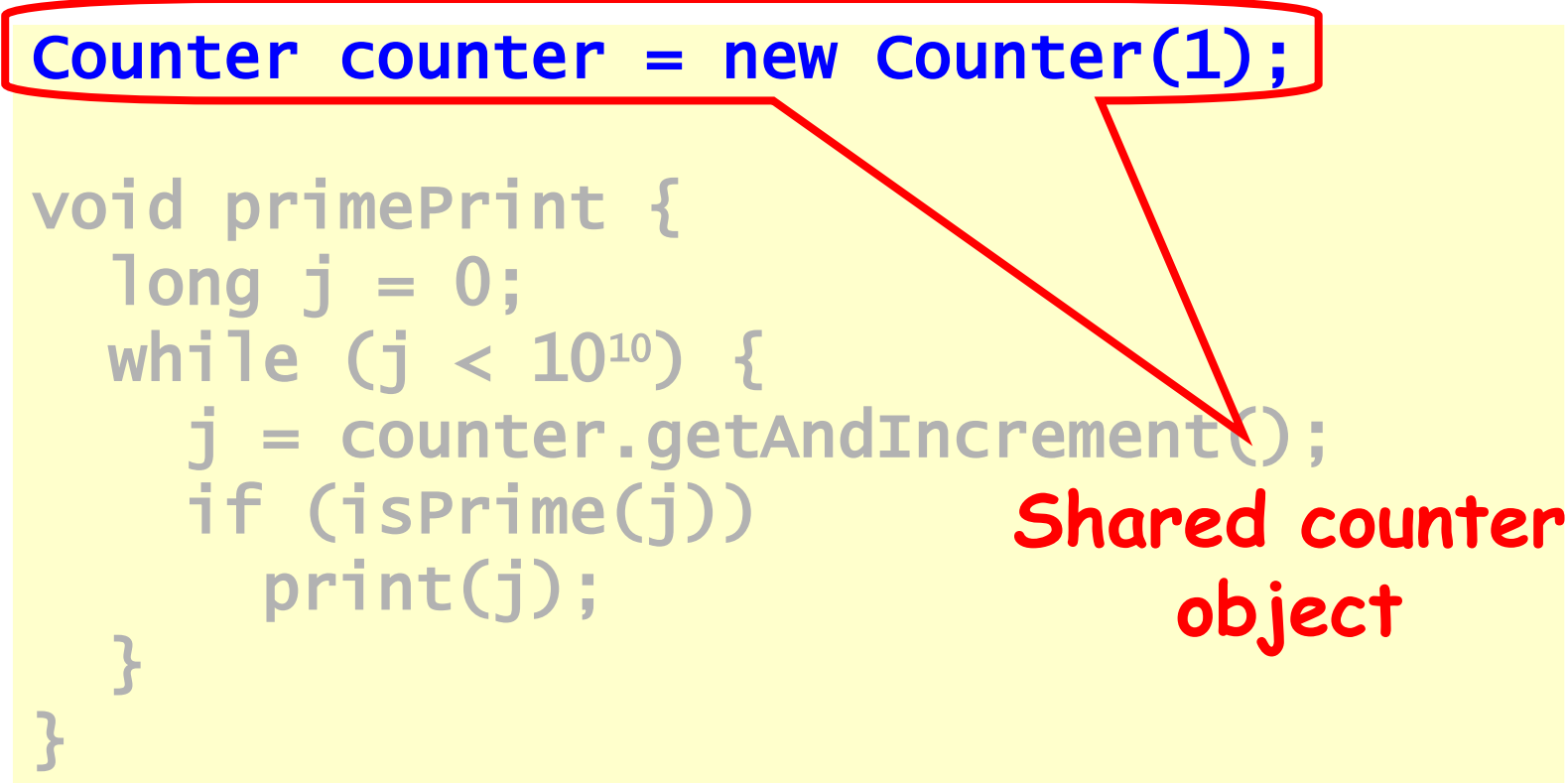
Procedure for Thread *i*

```
int counter = new Counter(1);

void primePrint {
    long j = 0;
    while (j < 1010) {
        j = counter.getAndIncrement();
        if (isPrime(j))
            print(j);
    }
}
```


Procedure for Thread *i*

Counter counter = new Counter(1);



```
void primePrint {  
    long j = 0;  
    while (j < 1010) {  
        j = counter.getAndIncrement();  
        if (isPrime(j))  
            print(j);  
    }  
}
```

**Shared counter
object**

Procedure for Thread *i*

```
Counter counter = new Counter(1);
```

```
void primePrint {
```

```
    long j = 0;
```

```
    while (j < 1010) {
```

```
        j = counter.getAndIncrement();
```

```
        if (isPrime(j))
```

```
            print(j);
```

```
    }
```

```
}
```

Stop when every
value taken

Procedure for Thread *i*

```
Counter counter = new Counter(1);
```

```
void primePrint {
```

```
    long j = 0;
```

```
    while (j < 1010) {
```

```
        j = counter.getAndIncrement();
```

```
        if (isPrime(j))
```

```
            print(j);
```

```
    }
```

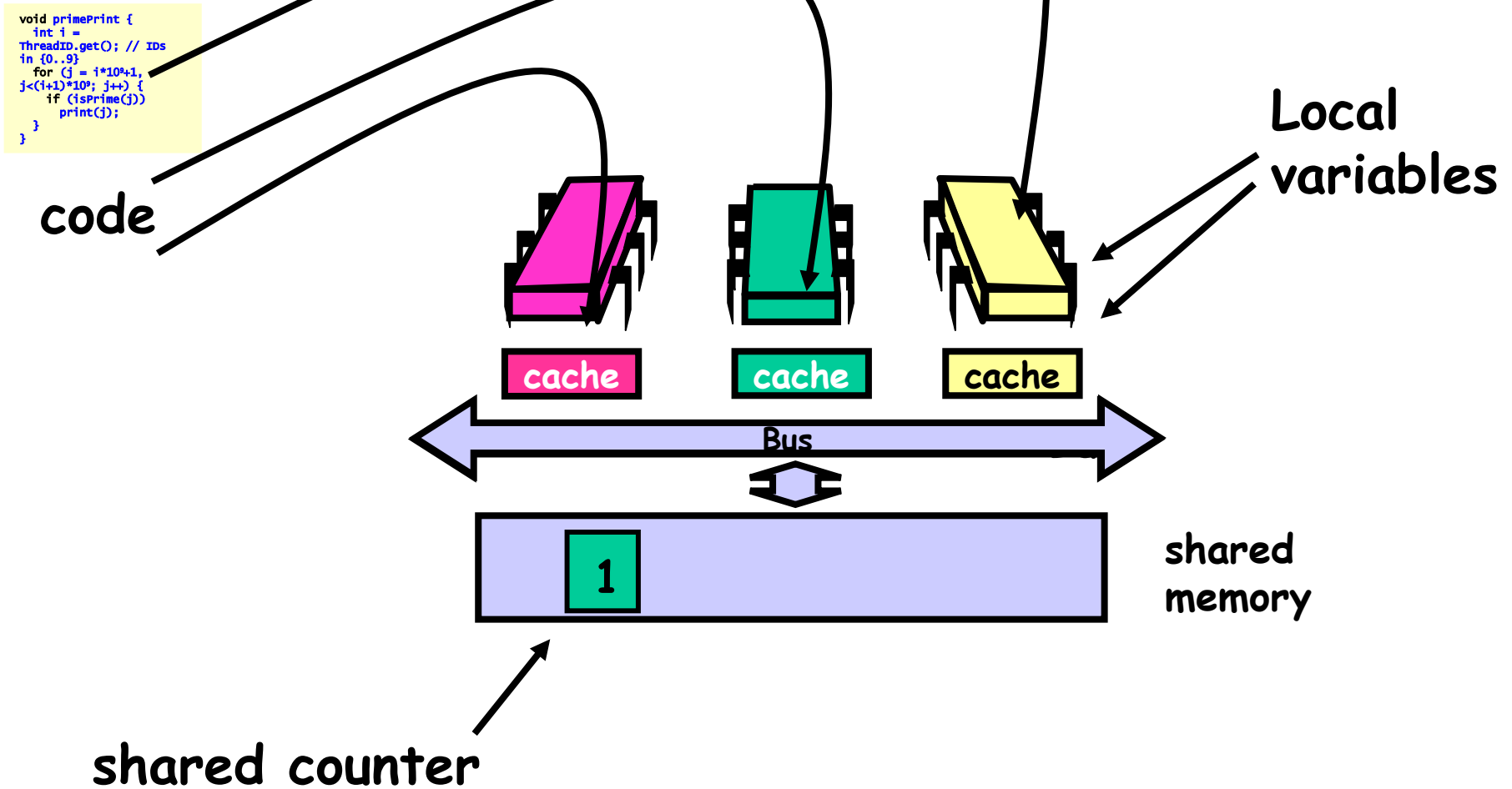
```
}
```

Increment &
return each new
value

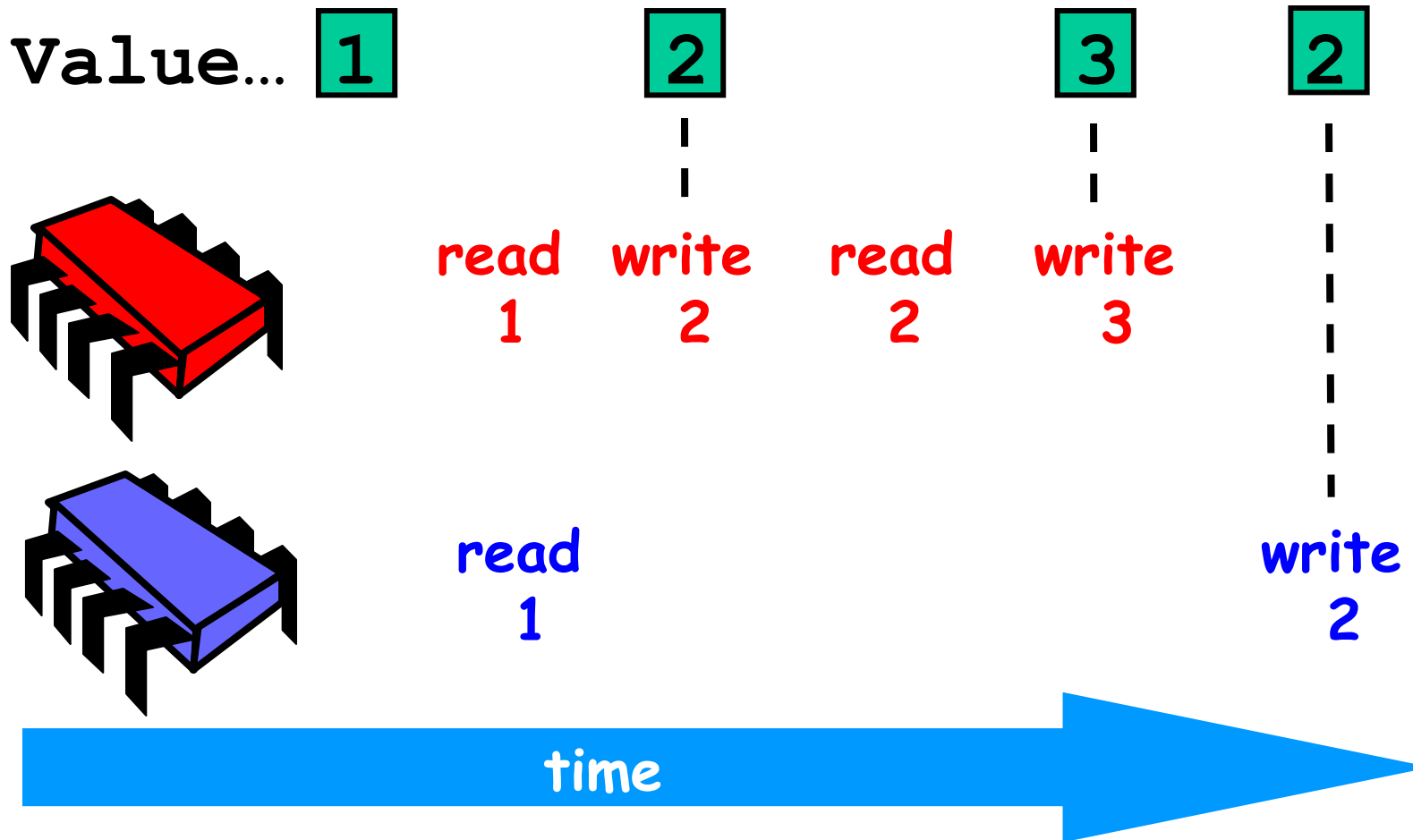
Counter Implementation

```
public class Counter {  
    private long value;  
  
    public long getAndIncrement() {  
        return value++;  
    }  
}
```

Where Things Reside



Not so good...



Challenge

```
public class Counter {  
    private long value;
```

```
    public long getAndIncrement() {  
        temp = value;  
        value = temp + 1;  
        return temp;  
    }  
}
```

**OK for single thread,
not for concurrent threads**

Challenge

```
public class Counter {  
    private long value;  
  
    public long getAndIncrement() {  
        temp = value;  
        value = temp + 1;  
        return temp;  
    }  
}
```

**Make these steps
atomic (indivisible)**

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