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# Java Memory Model
# JSR 133

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# Agenda of the day …

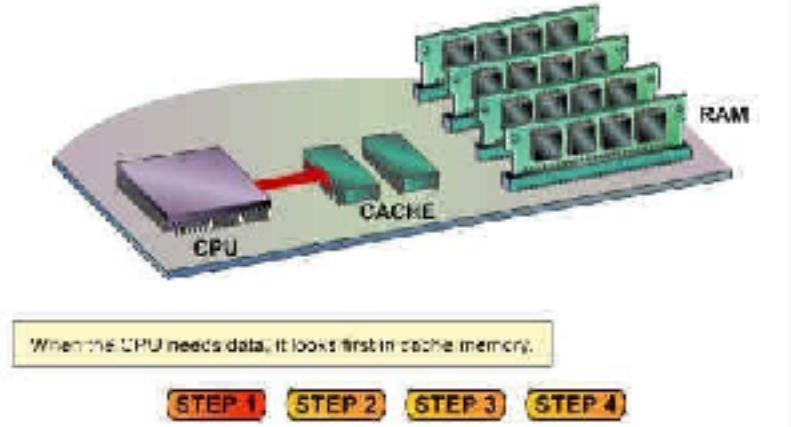
1. References
2. Threads
3. Locks
4. Volatile Variables
5. Data Races

# References

- Effective Java - By Joshua Bloch
- Concurrency in Practice - Brian Goetz
- JSR 133 - https://www.cs.umd.edu/users/pugh/java/memoryModel/
- JSR 133 FAQ - https://www.cs.umd.edu/~pugh/java/memoryModel/jsr-133-faq.html
- Chapter 17 of JLS - http://docs.oracle.com/javase/specs/jls/se8/html/jls-17.html#jls-17.4

# Java Memory Model - Why to know

- All about thread talking to memory.
- Cache brings great performance but created great challenges as well.
- Write to processor is visible to other thread ?
- Does your processor exhibits strong memory model or weak memory model ?
- When to invalidate cache data ?
  - Correctness vs performance (old fight)
- Compiler brings extra complication.



# Reordering issue

- Conspiracy by Compiler, JIT, cache.
- Illusion as-if-serial semantics, because they see the code for optimization from single thread eyes.
- Inconsistent behavior if seen from more than one thread.

# Java Memory Model

- Write once, Run Anywhere - Tough to achieve with processor level dependency.
- Java memory model is designed and it is part of JLS.
- Best practices **must be followed.**

# Memory Reordering on various architecture

| Type | Alpha | ARMv7 | PA-RISC | POWER | SPARC RMO | SPARC PSO | SPARC TSO | x86 | x86 oostore | AMD64 | IA-64 | z/Architecture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loads reordered after loads | Y | Y | Y | Y | Y | | | | Y | | Y | |
| Loads reordered after stores | Y | Y | Y | Y | Y | | | | Y | | Y | |
| Stores reordered after stores | Y | Y | Y | Y | Y | Y | | | Y | | Y | |
| Stores reordered after loads | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Atomic reordered with loads | Y | Y | | Y | Y | | | | | | Y | |
| Atomic reordered with stores | Y | Y | | Y | Y | Y | | | | | Y | |
| Dependent loads reordered | Y | | | | | | | | | | | |
| Incoherent instruction cache pipeline | Y | Y | | Y | Y | Y | Y | Y | Y | | Y | |

Reference: https://en.wikipedia.org/wiki/Memory_ordering

# Re-ordering issue

```
Class Reordering {
  int x = 0, y = 0;
  public void writer() {
    x = 1;
    y = 2;
  }

  public void reader() {
    int r1 = y;
    int r2 = x;
  }
}
```

| Possible Value | r1 | r2 |
|---|---|---|
| | 2 | 1 |
| | 0 | 1 |
| | 2 | 0 |

# Understanding Memory Barrier

```
int  data=0;
boolean ready = false;
```

```
void method1() {
    while (!ready) {};
    // need a barrier
    assert data == 42;
}
```

```
void method1() {
    data = 42;
    // need a barrier
    ready = true;
}
```

# Kinds of memory barrier

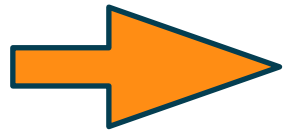
- Almost all processor supports coarse-grained barrier instruction called “Fence”.
- “Fence” guarantees that all the operations before fence will be strictly ordered before the operation after fence

- LoadLoad Barrier - Load1; Load-Load; Load2 means
  - Load1’s data is available before you access Load2’s data.
- StoreStore Barrier - Store1; Store-Store; Store2 means
  - Store1’s data are visible to other processor (flushed out) before Store2’s Data.

# Leads to “happened before” relationship

```
int  data=0;
boolean ready = false;
```

```
void synchronized method1() {
    while (!ready) {};
    assert data == 42;
}
```

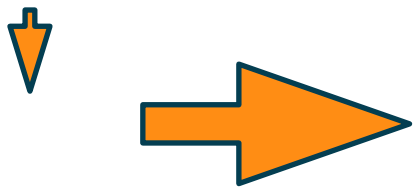


```
void synchronized method1() {
    data = 42;
    ready = true;
}
```

# volatile after JSR-133

```
int  data=0;
boolean volatile ready = false;
```

```
void synchronized method1() {
    while (!ready) {};
    assert data == 42;
}
```



```
void synchronized method1() {
    data = 42;
    ready = true;
}
```

# Volatile - will do it.

```
class VolatileExample {
  int x = 0;
  volatile boolean v = false;
  public void writer() {
    x = 42;
    v = true;
  }

  public void reader() {
    if (v == true) {
      //uses x - guaranteed to see 42.
    }
  }
}
```

# Work with final field

```
class FinalFieldExample {
  final int x;
  int y;
  static FinalFieldExample f;
  public FinalFieldExample() {
    x = 3;
    y = 4;
  }

  static void writer() {
    f = new FinalFieldExample();
  }

  static void reader() {
    if (f != null) {
      int i = f.x;  // 3 for sure
      int j = f.y;  // 4, not so sure
    }
  }
}
```

# Broken Double-check Singleton Pattern

```
// double-checked-locking - don't do this!

private static Something instance = null;

public Something getInstance() {
  if (instance == null) {
    synchronized (this) {
      if (instance == null)
        instance = new Something();
    }
  }
  return instance;
}
```

Details - http://www.javaworld.com/article/2074979/java-concurrency/double-checked-locking--clever--but-broken.html?page=2

# Unrevised Java Memory Model

- synchronized keyword
  - mutual exclusion
  - happened before
- volatile
  - visibility

**volatile doesn't establish a happened-before relationship**

**final values can change**

**many runtime optimizations where not allowed**

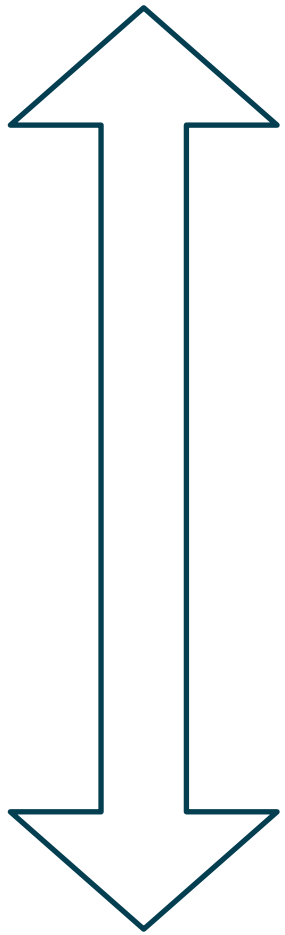
# Fix in Java 5 under JSR-133

- volatile **does** establish happen-before relationship.
- final values can’t change.
- Introduction of high level multi-threading library by Doug Lea and co.

- Read more - https://jcp.org/en/jsr/detail?id=133

# Avoid Low Level API

Abstract



java.util.concurrency, parallel streams

synchronized
- wait(), notify(), notifyAll()

Low Level

volatile, final …

# Breaking the spec

- Unexpected behavior on different architecture, OS, compiler.
- Intermittent failures.
- Always try to use high level concurrency package rather than low level data.