Assignment 4 Solution

Introduction to Databases

DataLab

CS, NTHU

Outline

- Useful Java Classes for Concurrency
- Lock Striping
- Summary of File & Buffer Optimization

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- Summary of File & Buffer Optimization

ReentrantLock

- An implementation of `Lock`
  - Provided in `java.util.concurrent.locks`
- A `ReentrantLock` has better performance than a `synchronized` block in multi-threading scenario

```
class X {
    private final ReentrantLock lock = new ReentrantLock();

    public void m() {
        lock.lock(); // block until condition holds
        try {
            // do something
        } finally {
            lock.unlock();
        }
    }
}
```

- See more here

ReentrantReadWriteLock

- An implementation of `ReadWriteLock`
  - Provided in `java.util.concurrent.locks`
- In addition to all functions `ReentrantLock` provide, `ReentrantReadWriteLock` also have `ReadLock` and `WriteLock`
  - A thread will be blocked during acquiring a `ReadLock` only if there is another thread holds a `WriteLock`
- See more here

ReentrantReadWriteLock

```
class Counter {
	// Locks
	private final ReentrantReadWriteLock rwLock = new ReentrantReadWriteLock();
	private final Lock rLock = rwLock.readLock();
	private final Lock wLock = rwLock.writeLock();

	// Value
	private int value = 0;

	public int get() {
		rLock.lock();
		try {
			return value;
		} finally {
			rLock.unlock();
		}
	}

	public void increment() {
		wLock.lock();
		try {
			value += 1;
		} finally {
			wLock.unlock();
		}
	}
}
```

ConcurrentHashMap

- A thread-safe `HashMap`
  - Provided in `java.util.concurrent`
- A `ConcurrentHashMap` works better than a synchronized `HashMap` which is just simply protected by synchronized blocks

- See more here

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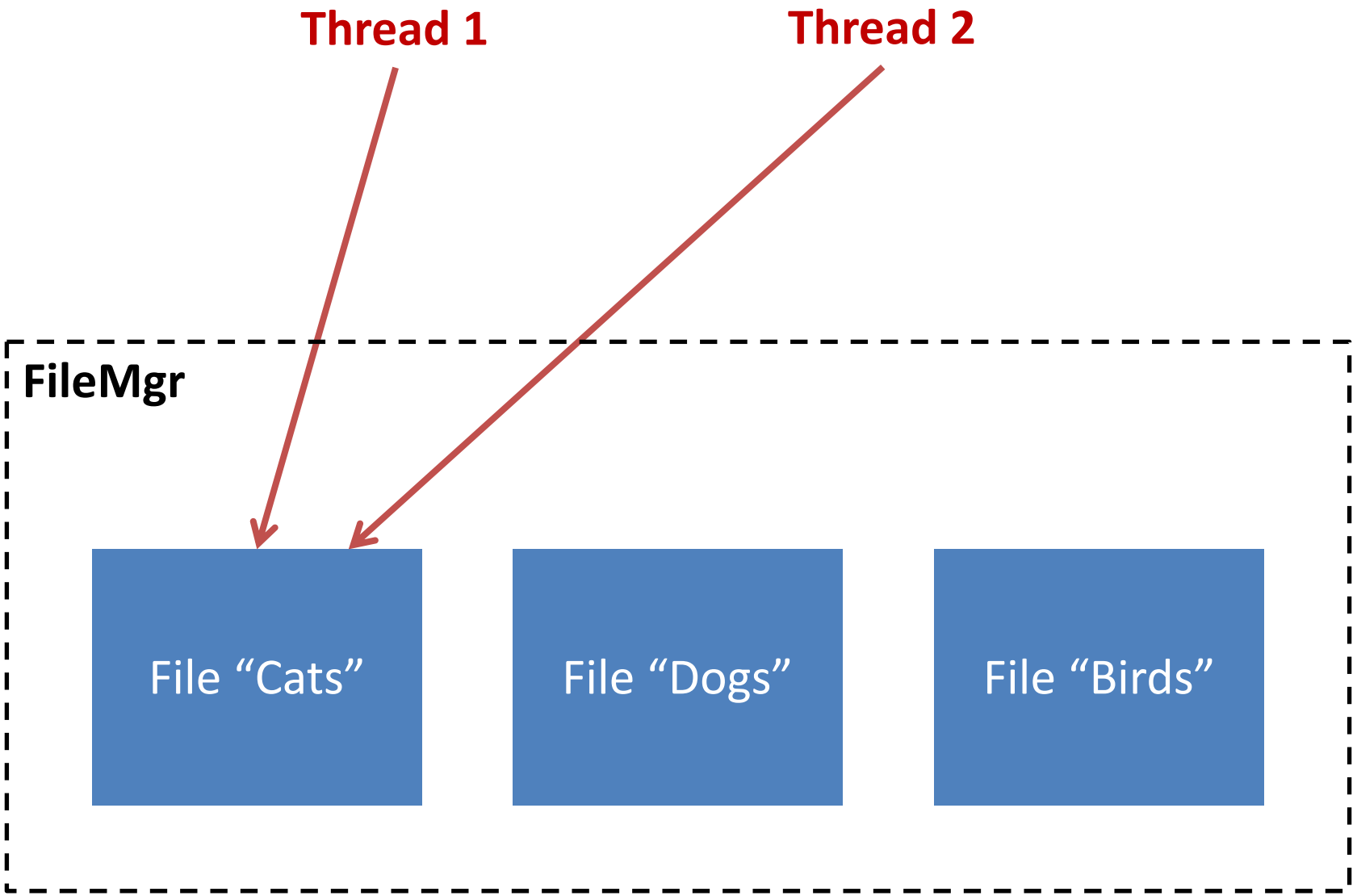
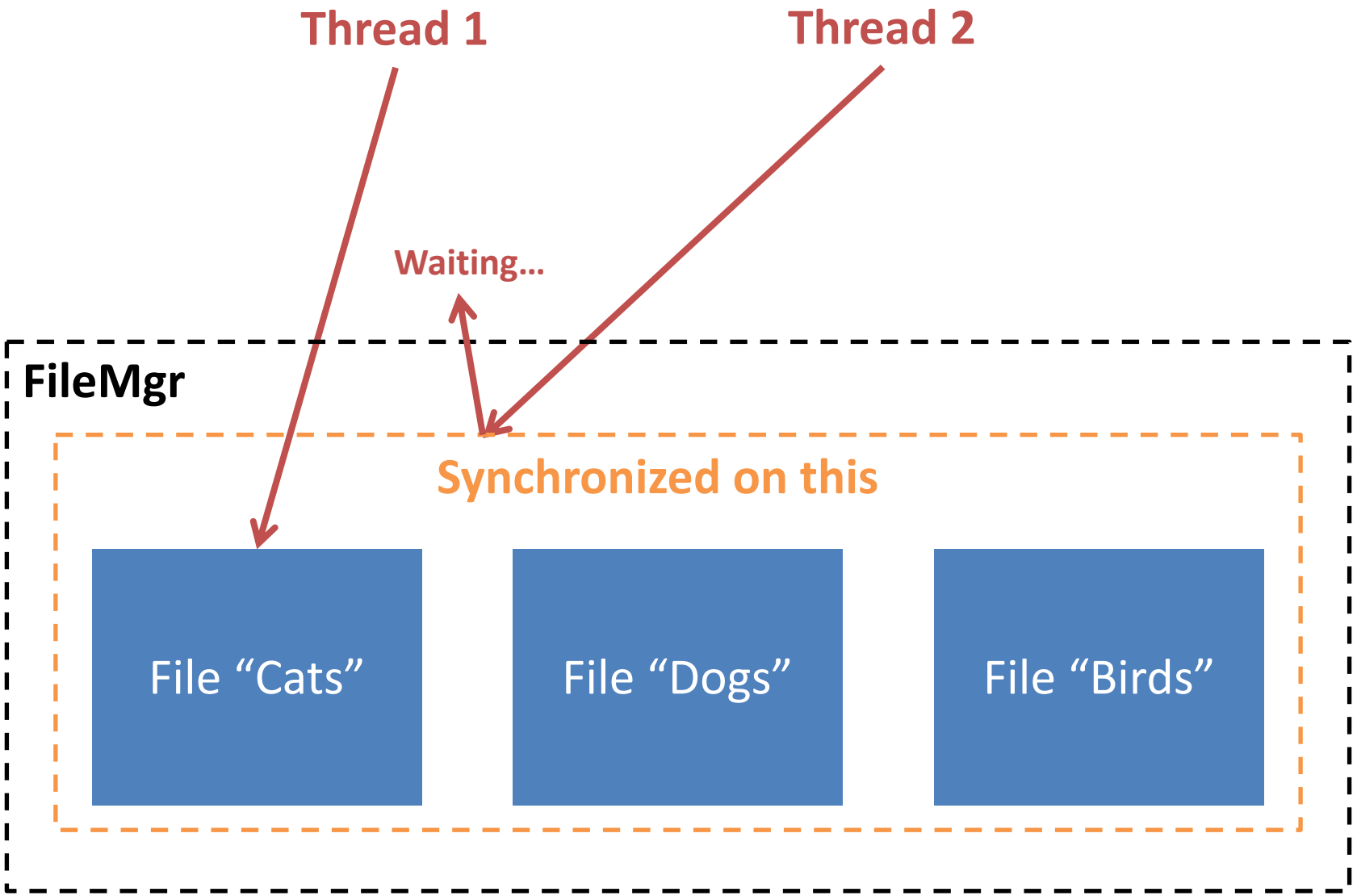
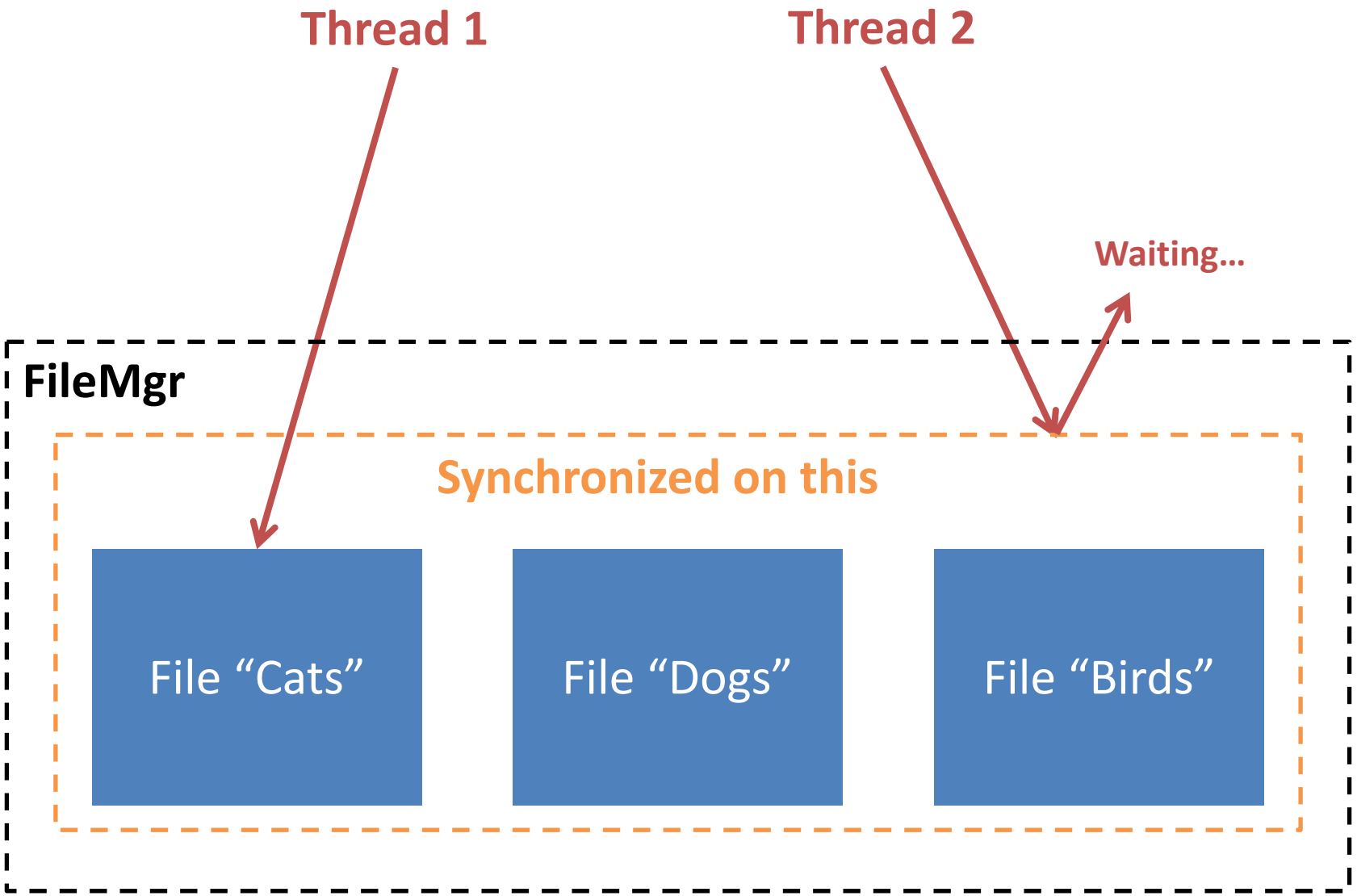
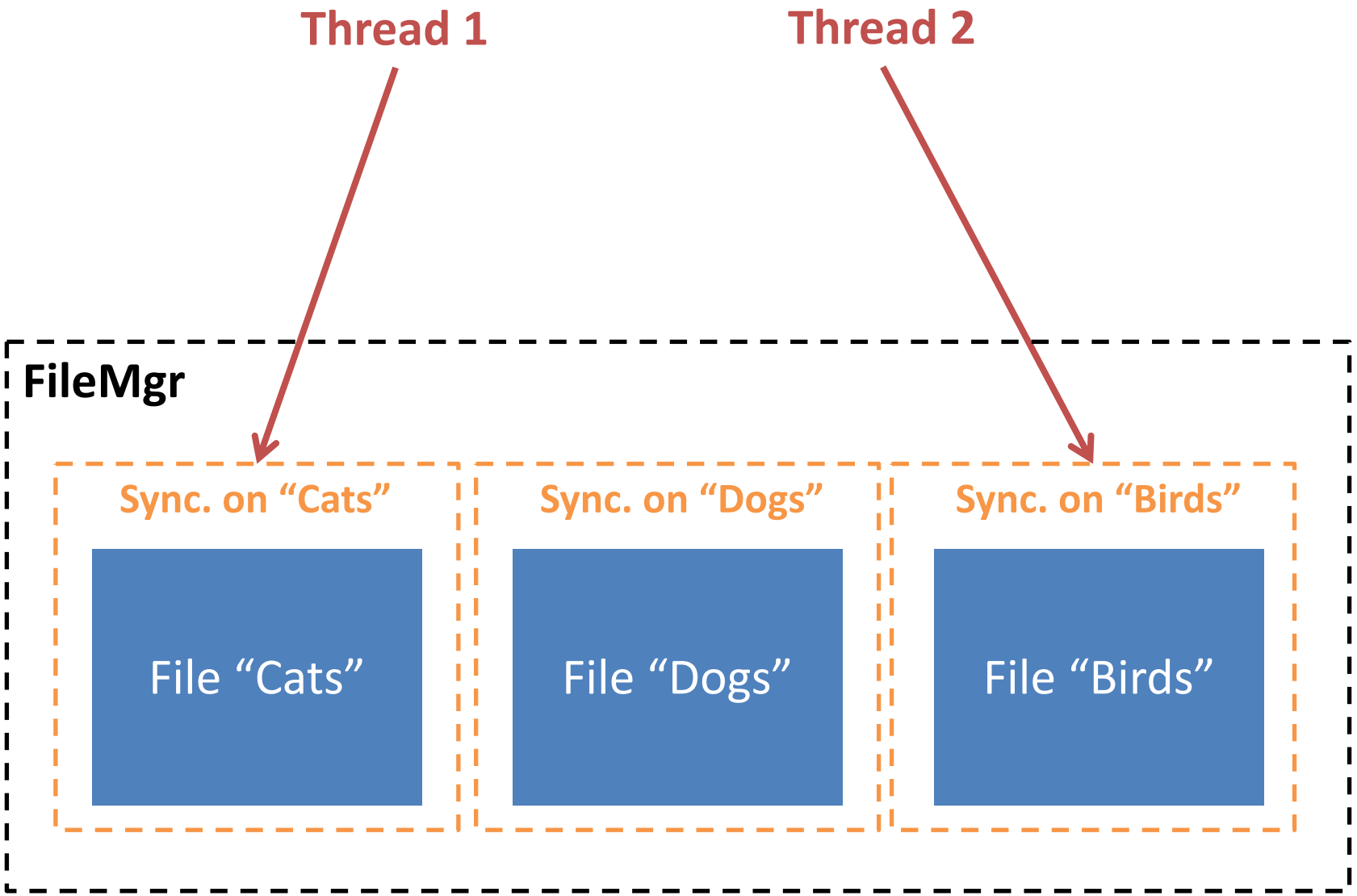

Thread 1
Thread 2
FileMgr
File “Cats”
File “Dogs”
File “Birds”


Thread 1
Thread 2
Waiting…
FileMgr
Synchronized on this
File “Cats”
File “Dogs”
File “Birds”


Thread 1
Thread 2
Waiting…
FileMgr
Synchronized on this
File “Cats”
File “Dogs”
File “Birds”


Thread 1
Thread 2
FileMgr
Sync. on “Cats”
Sync. on “Dogs”
Sync. on “Birds”
File “Cats”
File “Dogs”
File “Birds”

Global Synchronization

```
class ResourceMgr {

    private Map<String, Resource> resourcePool =
            new HashMap<String, Resource>();

    public synchronized void doSomething(String key) {
        Resource res = getResource(key);
        res.doAThing();
    }

    private Resource getResource(String key) {
        Resource res = resourcePool.get(key);

        if (res == null) {
            res = new Resource();
            resourcePool.put(key, res);
        }

        return res;
    }
}
```

Synchronization on Each Resource Object

```
class ResourceMgr {

     private Map<String, Resource> resourcePool =
               new HashMap<String, Resource>();

     public void doSomething(String key) {
          Resource res = getResource(key);

          synchronized (res) {
               res.doAThing();
          }
     }

     private Resource getResource(String key) {
          Resource res = resourcePool.get(key);

          if (res == null) {
               res = new Resource();
               resourcePool.put(key, res);
          }

          return res;
     }
}
```

Lock on the required object

There is a problem here

Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```

Pool

Thread 1 key="meow" **res** = NULL

Thread 2 key="meow" **res** = NULL

Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```

Resource 1

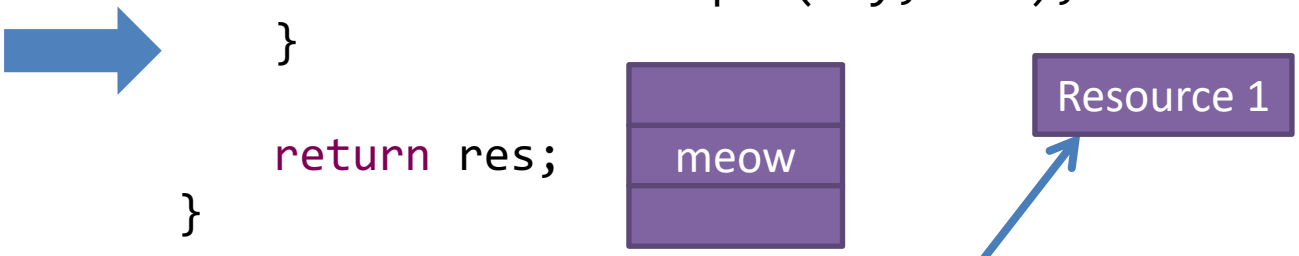
Pool

Thread 1 key="meow" **res** = NULL

Thread 2 key="meow" **res** = NULL

Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```

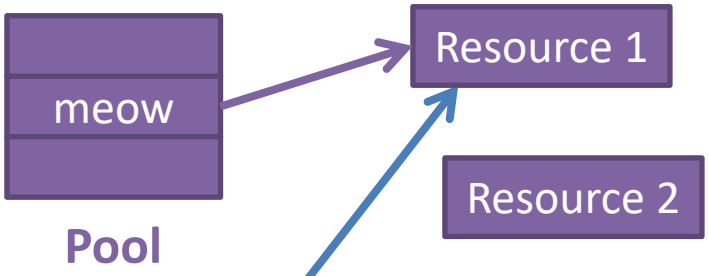


Thread 1 key="meow" **res**

Thread 2 key="meow" **res = NULL**

Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```

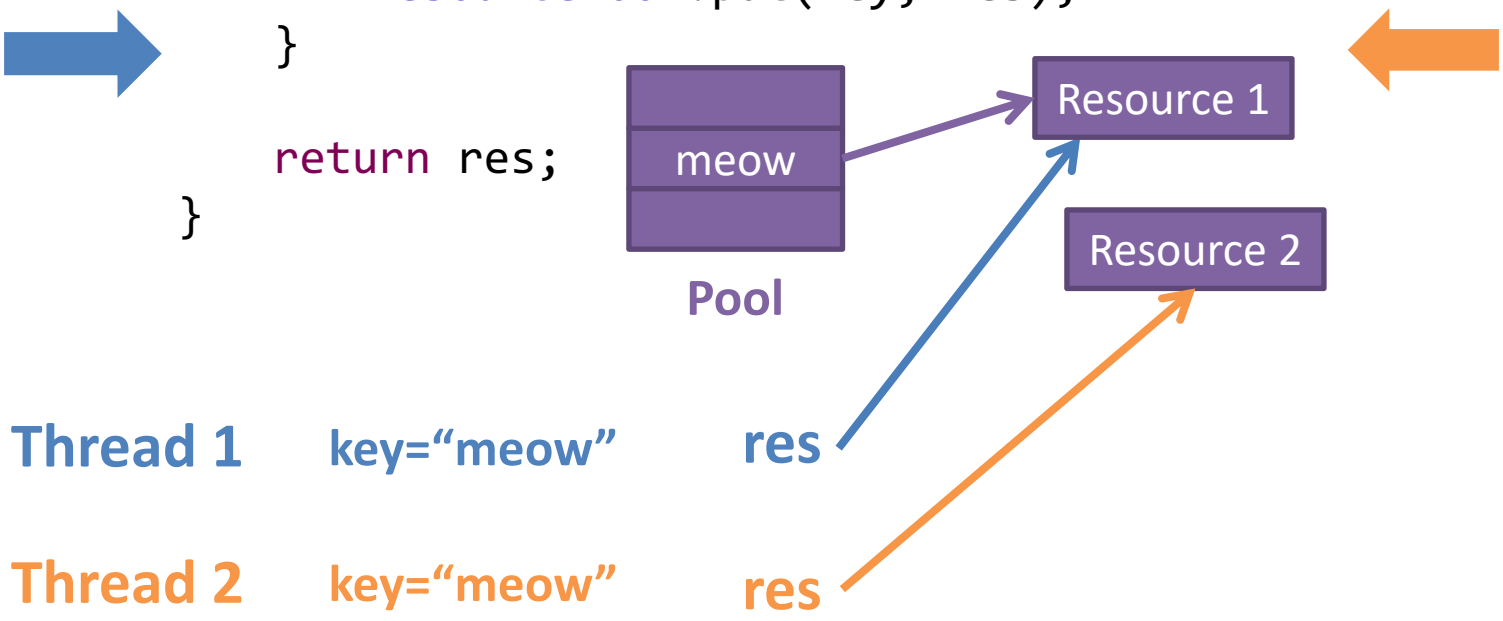


Thread 1 key="meow" res

Thread 2 key="meow" res = NULL

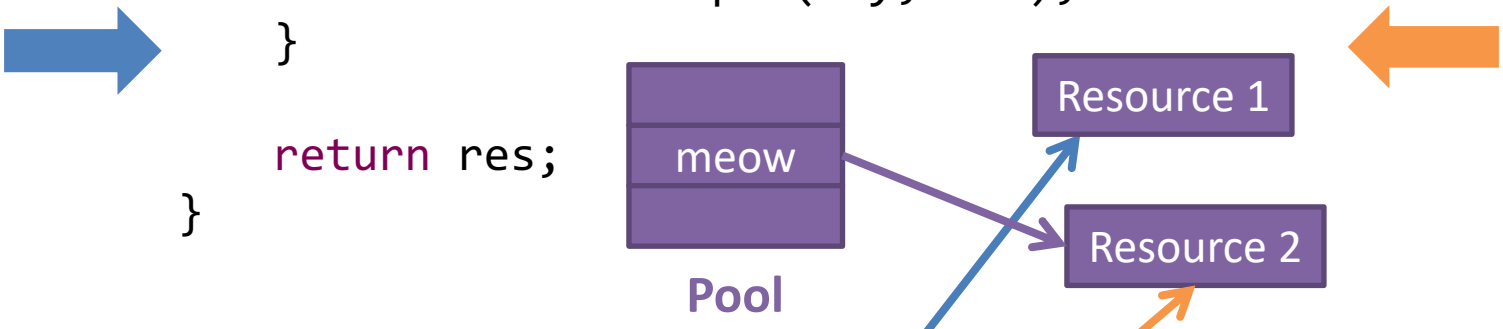
Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```



Race Condition

```
private Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```



Thread 1 key="meow" res

Thread 2 key="meow" res

There are two resource with the same key !!
And only 1 can be found

Solution

The problem solved, but not good enough

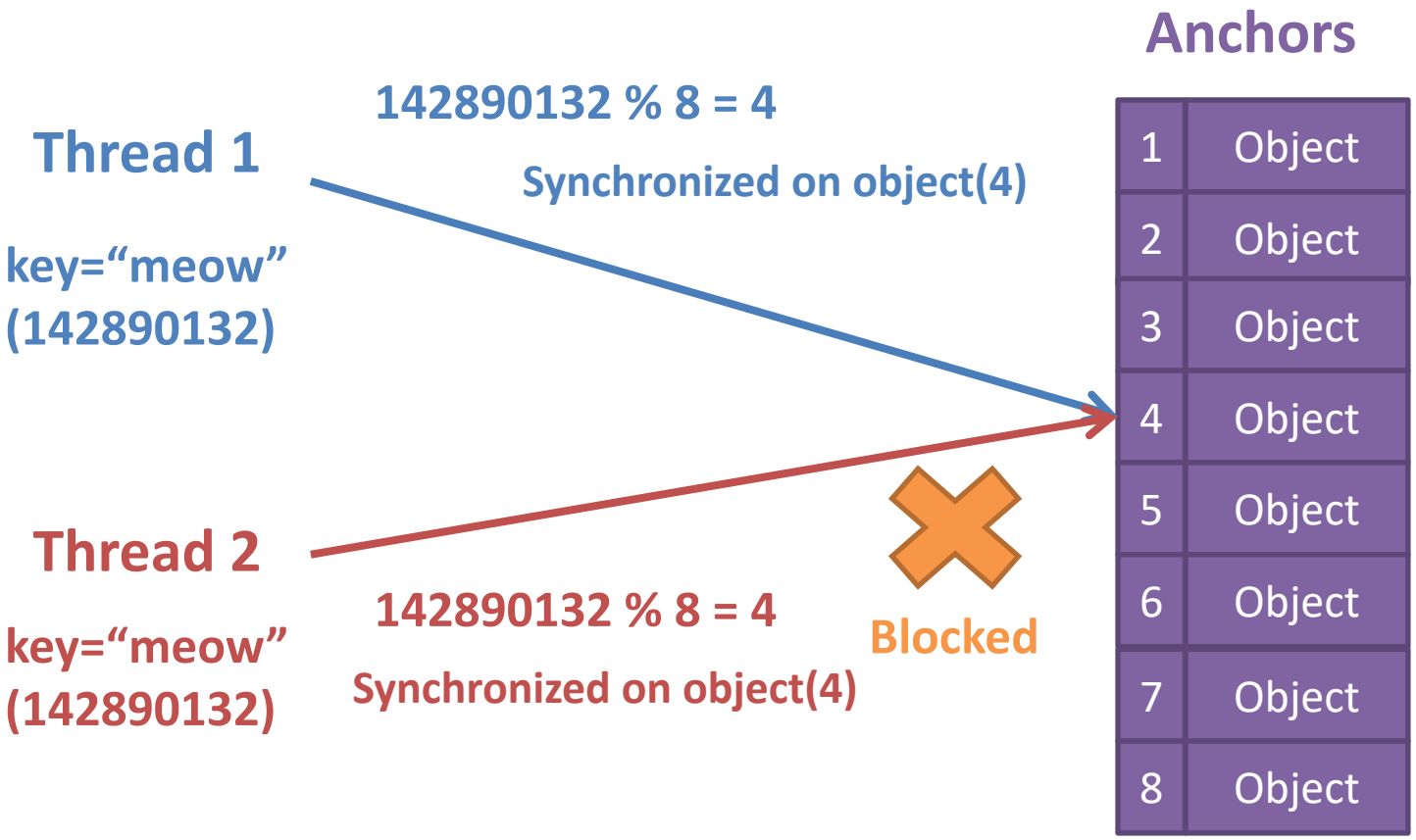
```
private synchronized Resource getResource(String key) {
    Resource res = resourcePool.get(key);

    if (res == null) {
        res = new Resource();
        resourcePool.put(key, res);
    }

    return res;
}
```

Can We Do Even Better?

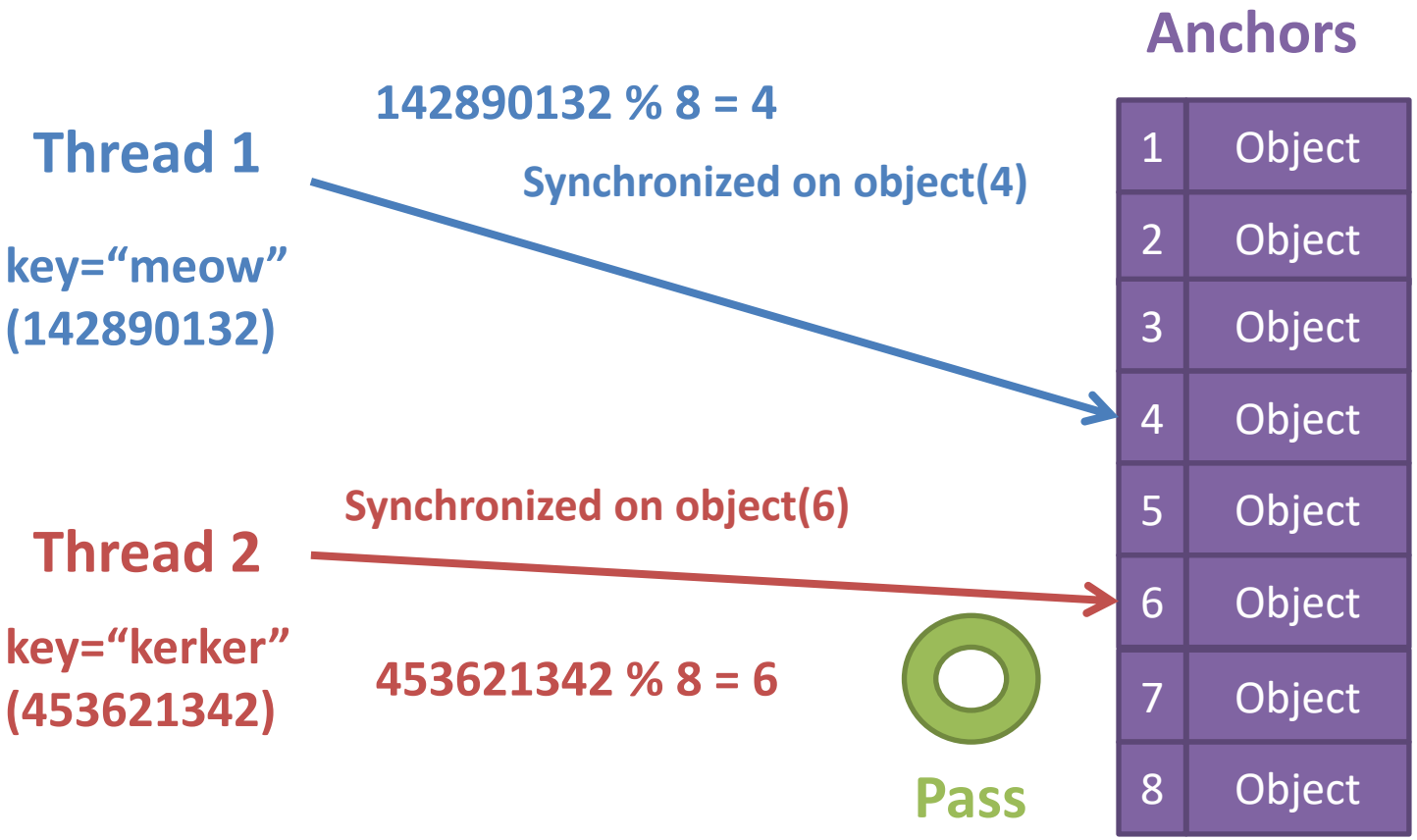
Lock Striping

- Lock striping basically uses a fixed-size, shared collection of locks to reduce the contention on the same object

Lock Striping



Lock Striping



Final Solution

```
private Object[] anchors = new Object[100];

private Object getAnchor(String key) {
    return anchors[key.hashCode() % anchors.length];
}

private Resource getResource(String key) {
    synchronized (getAnchor(key)) {
        Resource res = resourcePool.get(key);

        if (res == null) {
            res = new Resource();
            resourcePool.put(key, res);
        }

        return res;
    }
}
```

Don’t forget to use ConcurrentHashMap for resource pool

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- Useful Java Classes for Concurrency
- Lock Striping
- Summary of File & Buffer Optimization

File Optimization

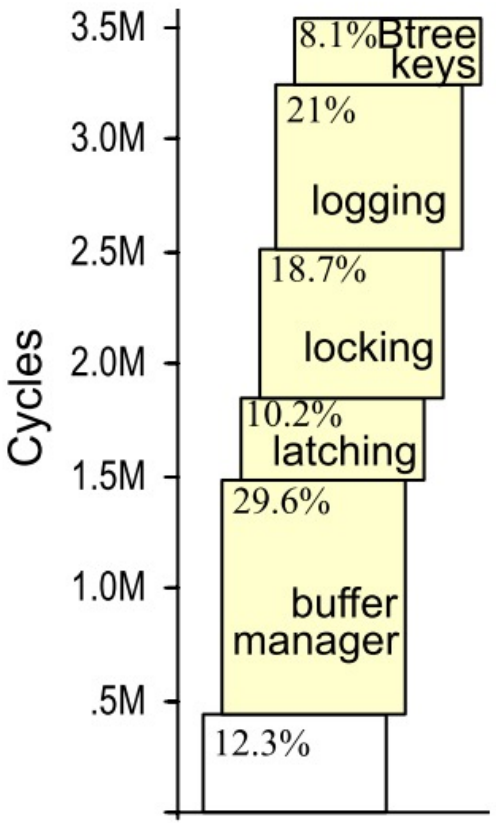
- Read Write Lock
  - We use `RentreenReadWriteLock` in each `IoChannel`, use `ReadLock` for reading and `WriteLock` for modifications
- Lock Striping
  - Use lock-striping in `getFileChannel()`
- Caching
  - Cache the hashcode of `BlockId`

Buffer Optimization

- Reduce the size of critical section as small as possible
  - e.g. `BufferMgr.pin()` and `pinNew()`
- Read Write Lock
  - For each `Buffer`
- Lock Striping
  - In `BufferPoolMgr.pin()` and `pinNew()`
- Improved Clock Strategy

Some Research on `pin()`

- According to a research [1], txs usually take more time in buffer manager than in other modules
- Some researchers of HP lab found `pin()` is a big bottleneck when traversing B-tree indexes [2]
  - They purposed a new way to optimize buffer manager for B-tree indexes



[1] "OLTP Through the Looking Glass, and What We Found There." in SIGMOD'08
[2] "In-Memory Performance for Big Data" in VLDB'14