

# VanillaCore Walkthrough

## Part 3

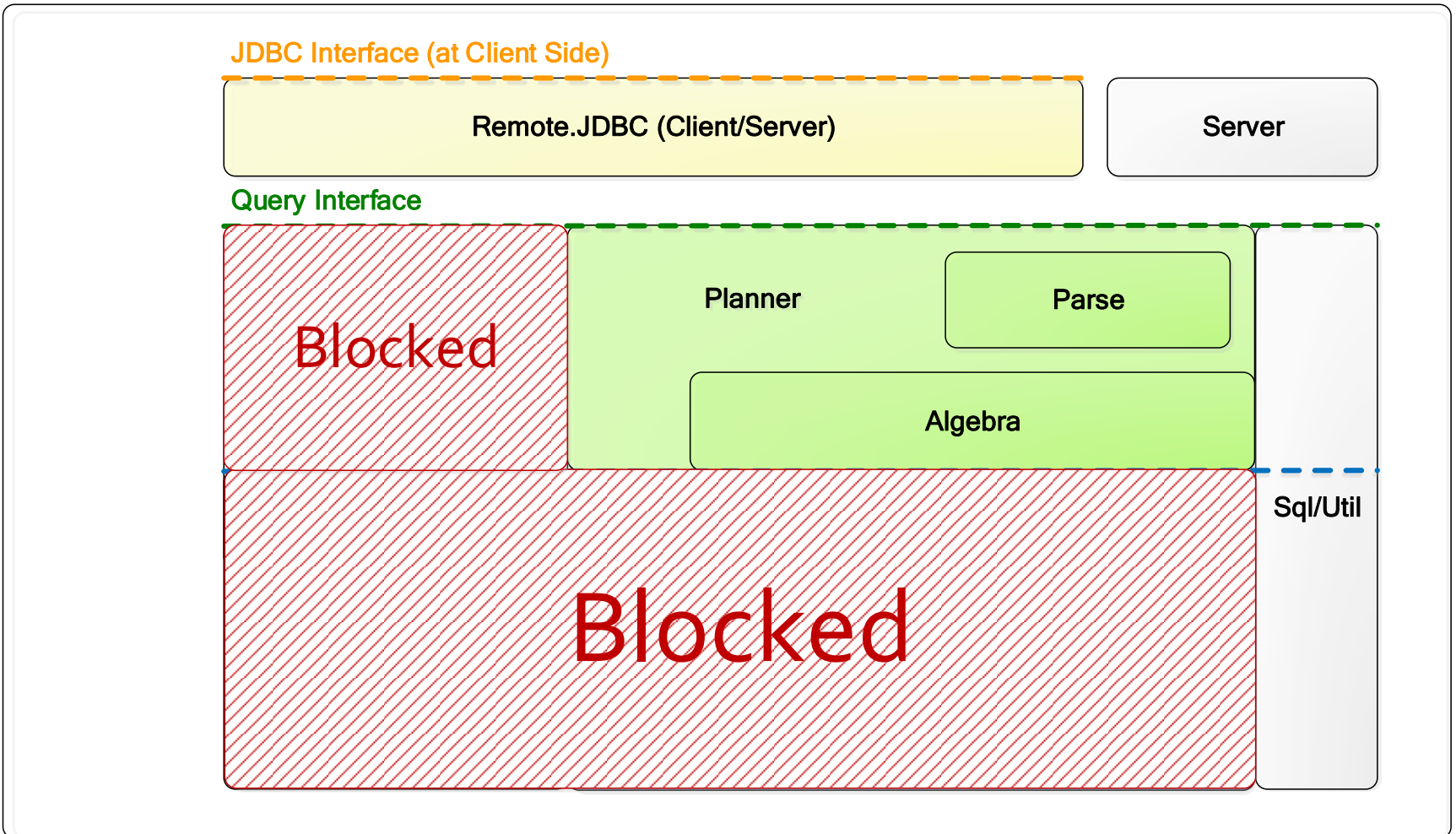
Introduction to Databases

DataLab

CS, NTHU

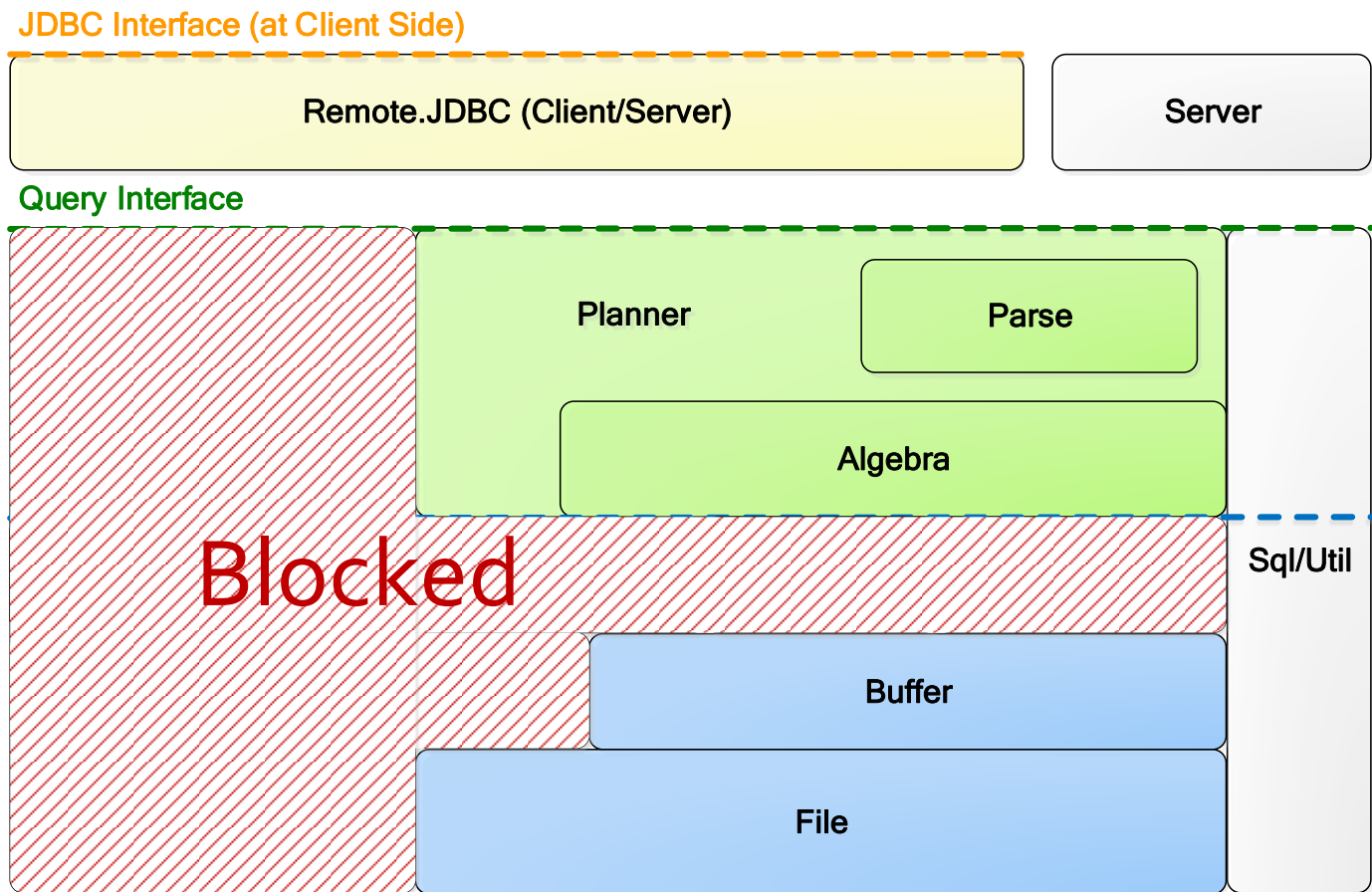
# Last Time

VanillaDB



# This Time

VanillaDB



# Outline

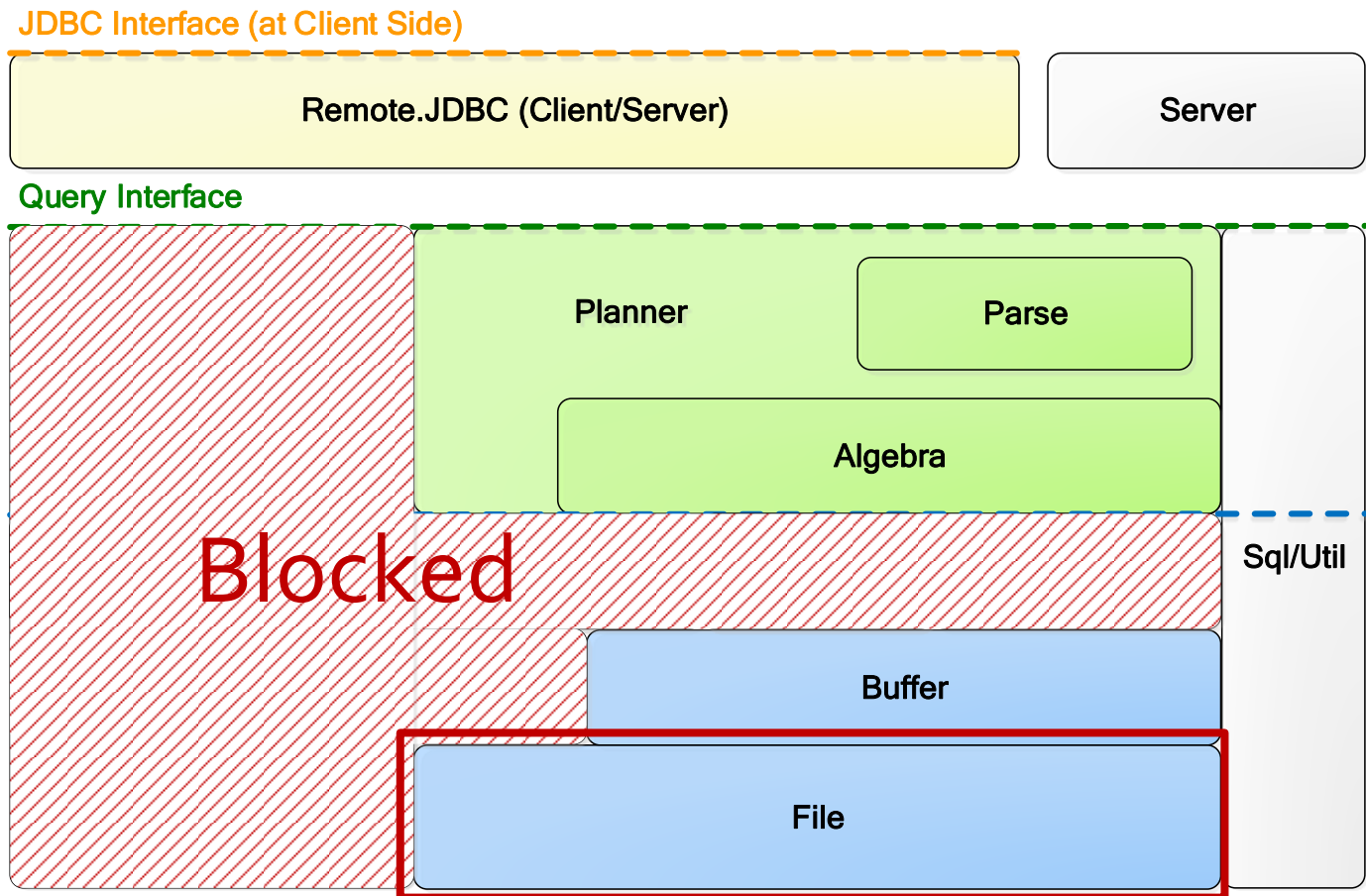
- File package
- Buffer package

# Outline

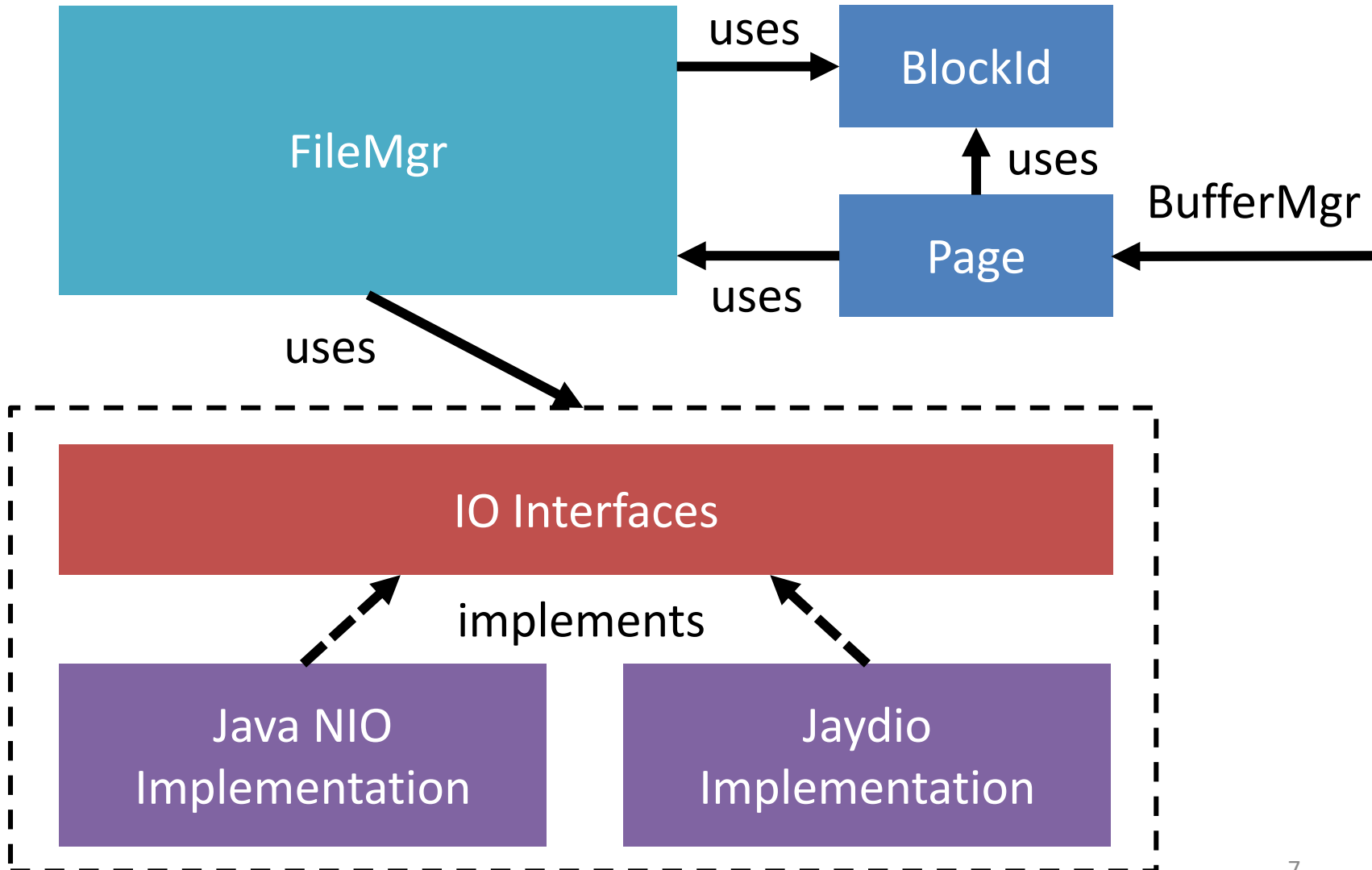
- File package
- Buffer package

# Where are we?

VanillaDB



# file Package



# BlockId

```
public class BlockId {  
    private String fileName;  
    private long blkNum;  
  
    public BlockId(String fileName, long blkNum) {  
        this.fileName = fileName;  
        this.blkNum = blkNum;  
    }  
  
    public String fileName() {  
        return fileName;  
    }  
  
    public long number() {  
        return blkNum;  
    }  
    ...  
}
```

| BlockId  |
|--|
|  |
| + BlockId(filename : String, blknum : long)<br>+ fileName() : String<br>+ number() : long<br>+ equals(Object : obj) : boolean<br>+ toString() : String<br>+ hashCode() : int |



# Page

| Page   |
|--|
| <u>&lt;&lt;final&gt;&gt; + BLOCK_SIZE : int</u>  |
| <u>+ maxSize(type : Type) : int</u><br><u>+ size(val : Constant) : int</u><br><br>+ Page()<br><<synchronized>> + read(blk : BlockId)<br><<synchronized>> + write(blk : BlockId)<br><<synchronized>> + append(filename : String) : BlockId<br><<synchronized>> + getVal(offset : int, type : Type) : Constant<br><<synchronized>> + setVal(offset : int, val : Constant)<br>+ close() |

# Page

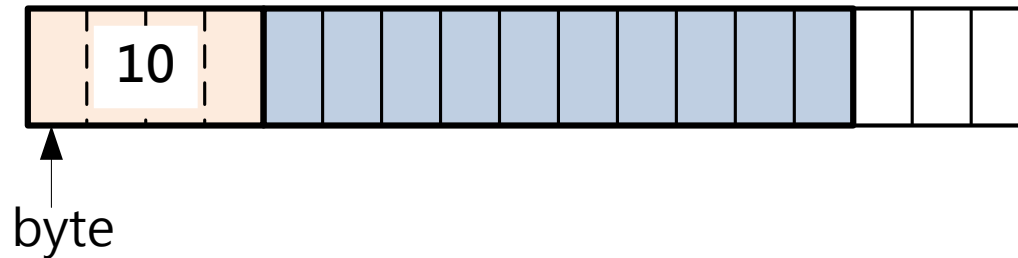
- Backed by `IoBuffer`

```
private IoBuffer contents = IoAllocator.newIoBuffer(BLOCK_SIZE);
```

- Translate constants using `Constant.asBytes()`
  - Fixed length for numeric type constants (e.g., 4 bytes for `IntegerConstant`)
  - Variable length for `VarcharConstant`
- How to reconstruct a varchar constant in getter?

# Storing A Varchar

- Page stores a Varchar in two parts
  - The first is the length of those bytes
  - The second is the bytes from `asByte()`



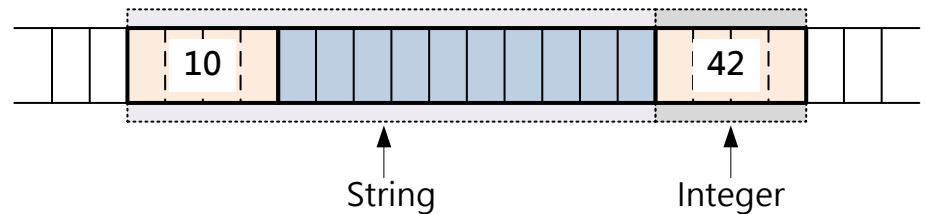
# setVal

```
public synchronized void setVal(int offset, Constant val) {
    byte[] byteval = val.asBytes();

    // Append the size of value if it is not fixed size
    if (!val.getType().isFixedSize()) {
        // check the field capacity and value size
        if (offset + ByteHelper.INT_SIZE + byteval.length > BLOCK_SIZE)
            throw new BufferOverflowException();

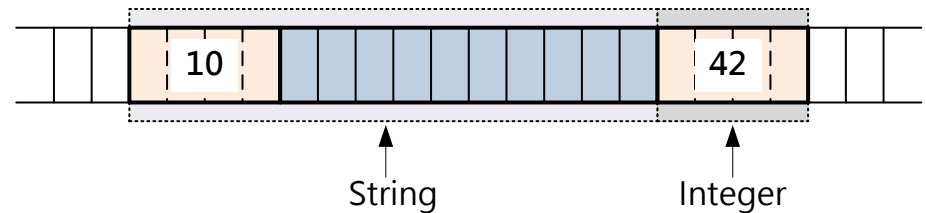
        byte[] sizeBytes = ByteHelper.toBytes(byteval.length);
        contents.put(offset, sizeBytes);
        offset += sizeBytes.length;
    }

    // Put bytes
    contents.put(offset, byteval);
}
```



# getVal

```
public synchronized Constant getVal(int offset, Type type) {  
    int size;  
    byte[] byteVal = null;  
  
    // Check the length of bytes  
    if (type.isFixedSize()) {  
        size = type.maxSize();  
    } else {  
        byteVal = new byte[ByteHelper.INT_SIZE];  
        contents.get(offset, byteVal);  
        size = ByteHelper.toInteger(byteVal);  
        offset += ByteHelper.INT_SIZE;  
    }  
  
    // Get bytes and translate it to Constant  
    byteVal = new byte[size];  
    contents.get(offset, byteVal);  
    return Constant.newInstance(type, byteVal);  
}
```



# Sizing Information

- There are static APIs providing sizing information in Page

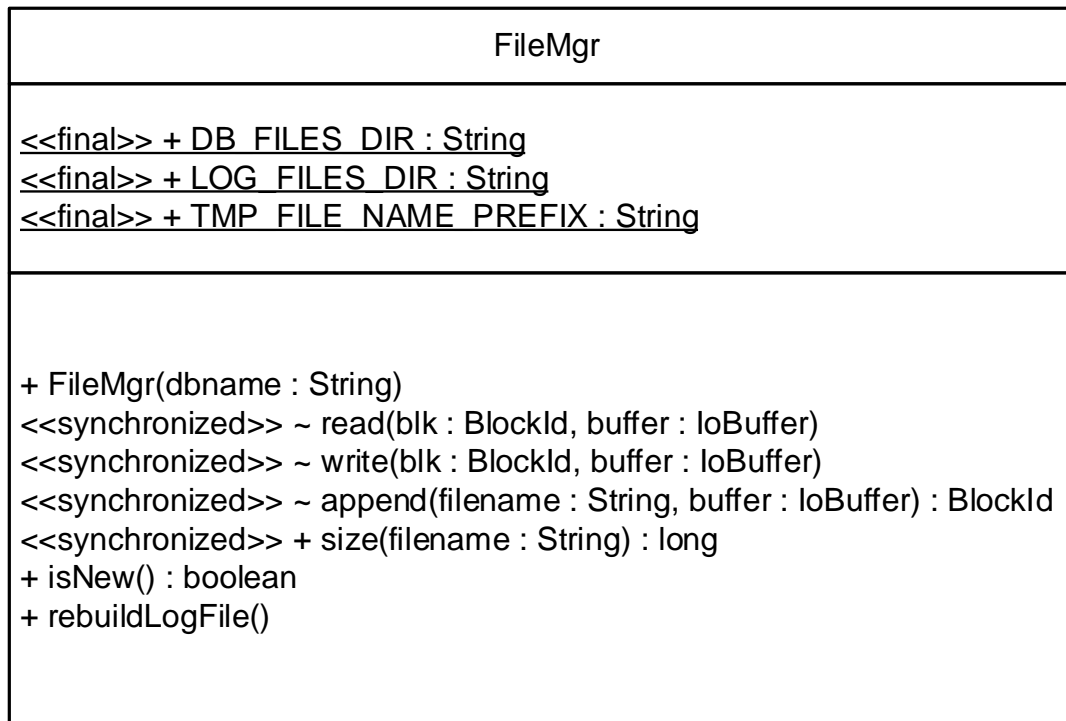
```
public static int maxSize(Type type) {  
    return type.isFixedSize() ? type.maxSize() : ByteHelper.INT_SIZE  
        + type.maxSize();  
}  
  
public static int size(Constant val) {  
    return val.getType().isFixedSize() ? val.size() : ByteHelper.INT_SIZE  
        + val.size();  
}
```

# File I/Os

```
public Page() {  
}  
  
public synchronized void read(BlockId blk) {  
    fileMgr.read(blk, contents);  
}  
  
public synchronized void write(BlockId blk) {  
    fileMgr.write(blk, contents);  
}  
  
public synchronized BlockId append(String fileName) {  
    return fileMgr.append(fileName, contents);  
}
```

# FileMgr

- Handles the actual I/Os
- Keeps the `IoChannel` instances of all opened files

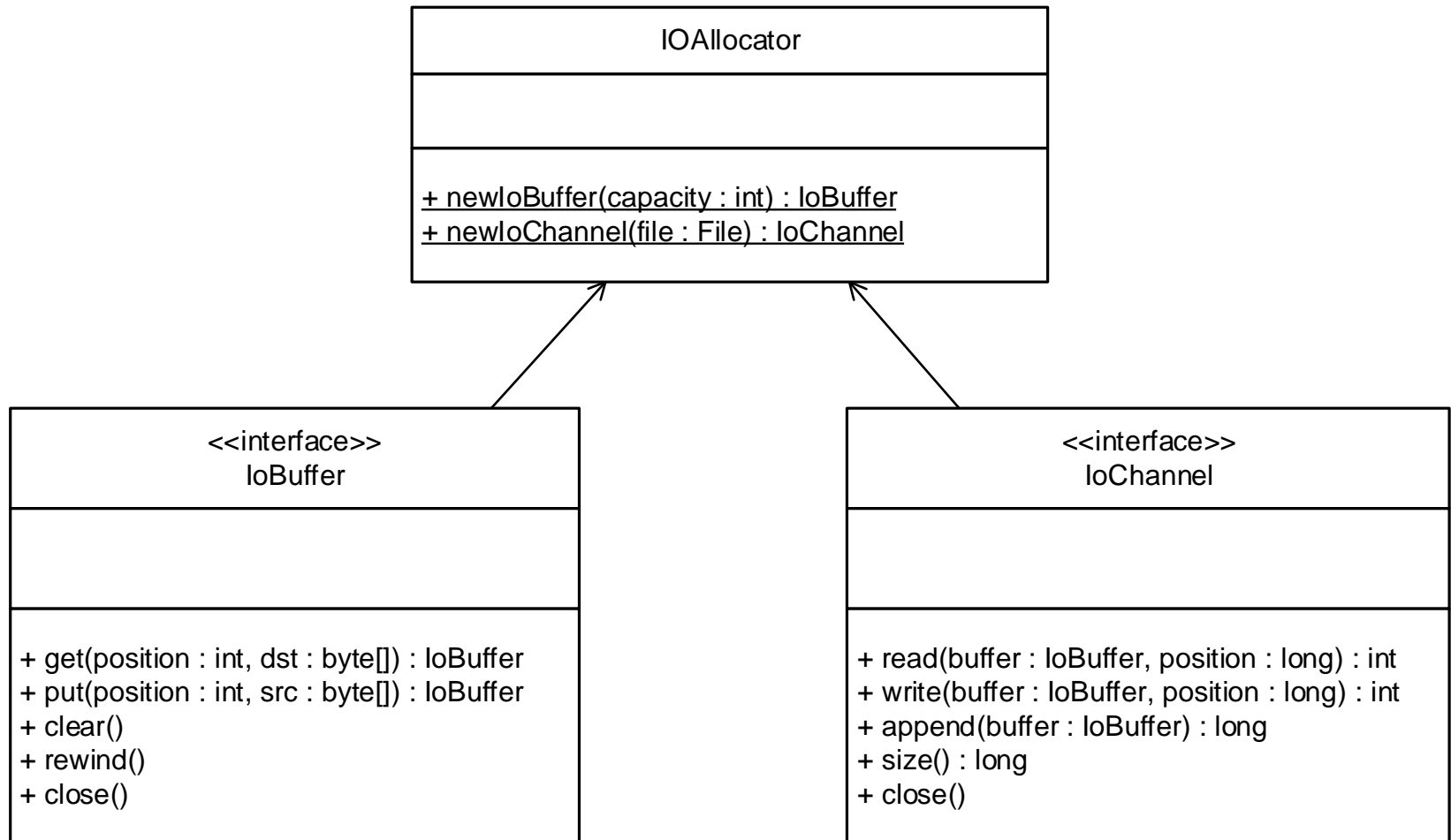




# FileMgr

- A page delegates read, write and, append to FileMgr
- Note that the file manager always reads/writes/appends a **block-sized** number of bytes from/to a file
  - Exactly one disk access per call

# file.io



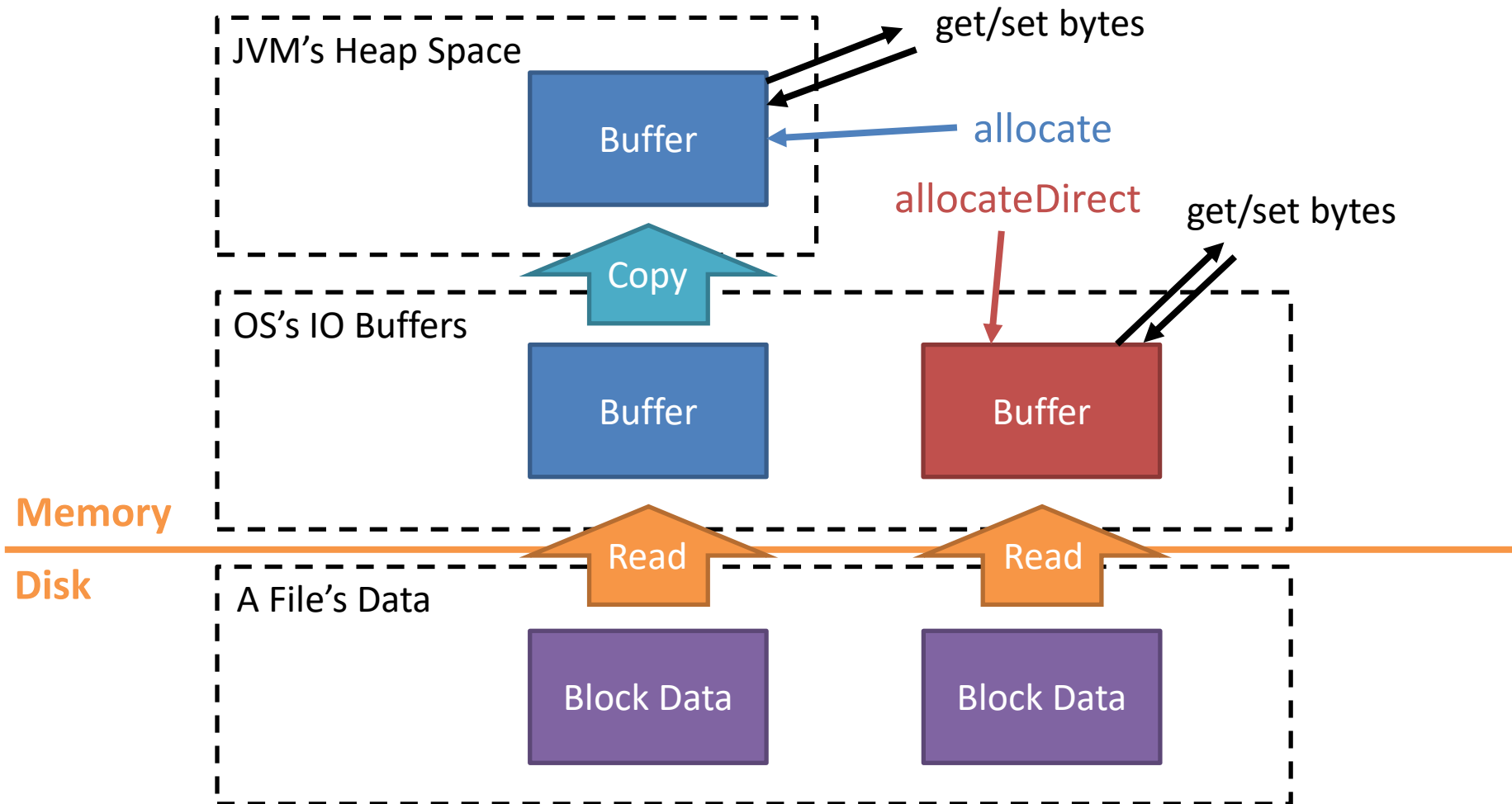
# IoChannel in Java NIO

- Opens a file by creating a new `RandomAccessFile` instance and then obtain its file channel via `getChannel()`
- Files are open in “rws” mode when using Java NIO
  - The “rw” means that the file is open for reading and writing
  - The “s” means that the OS should not delay disk I/O in order to optimize disk performance; instead, every *write* operation must be written immediately to the disk

# IoBuffer in Java NIO

- We don't want the memory space of `ByteBuffer` be swapped out by OS
- `ByteBuffer` has two factory methods: `allocate` and `allocateDirect`
  - `allocateDirect` tells JVM to use one of the OS's I/O buffers to hold the bytes
  - ***Not*** in Java programmable buffer, no garbage collection
  - Eliminates the redundancy of ***double buffering***

# Double Buffering

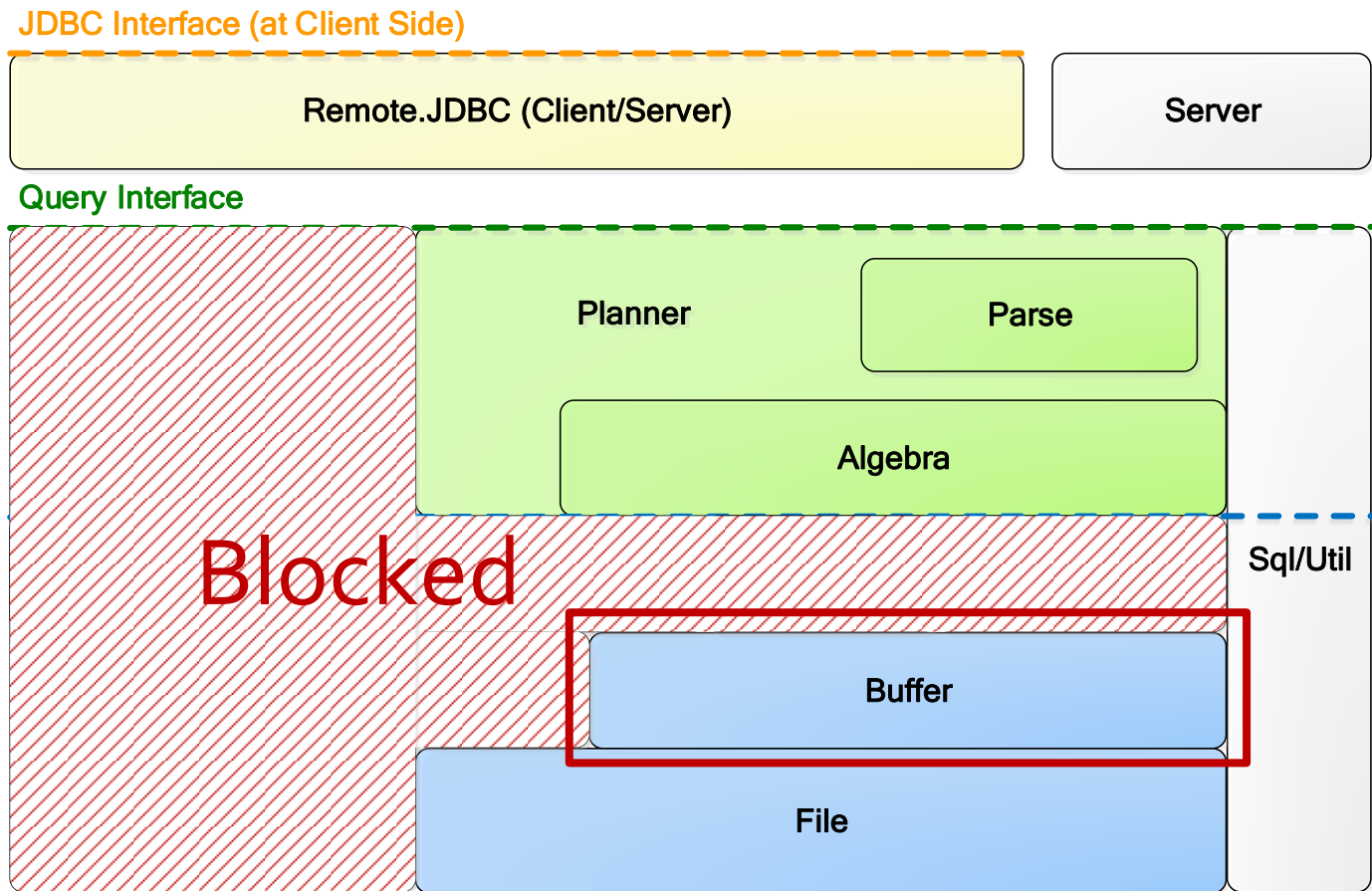


# Outline

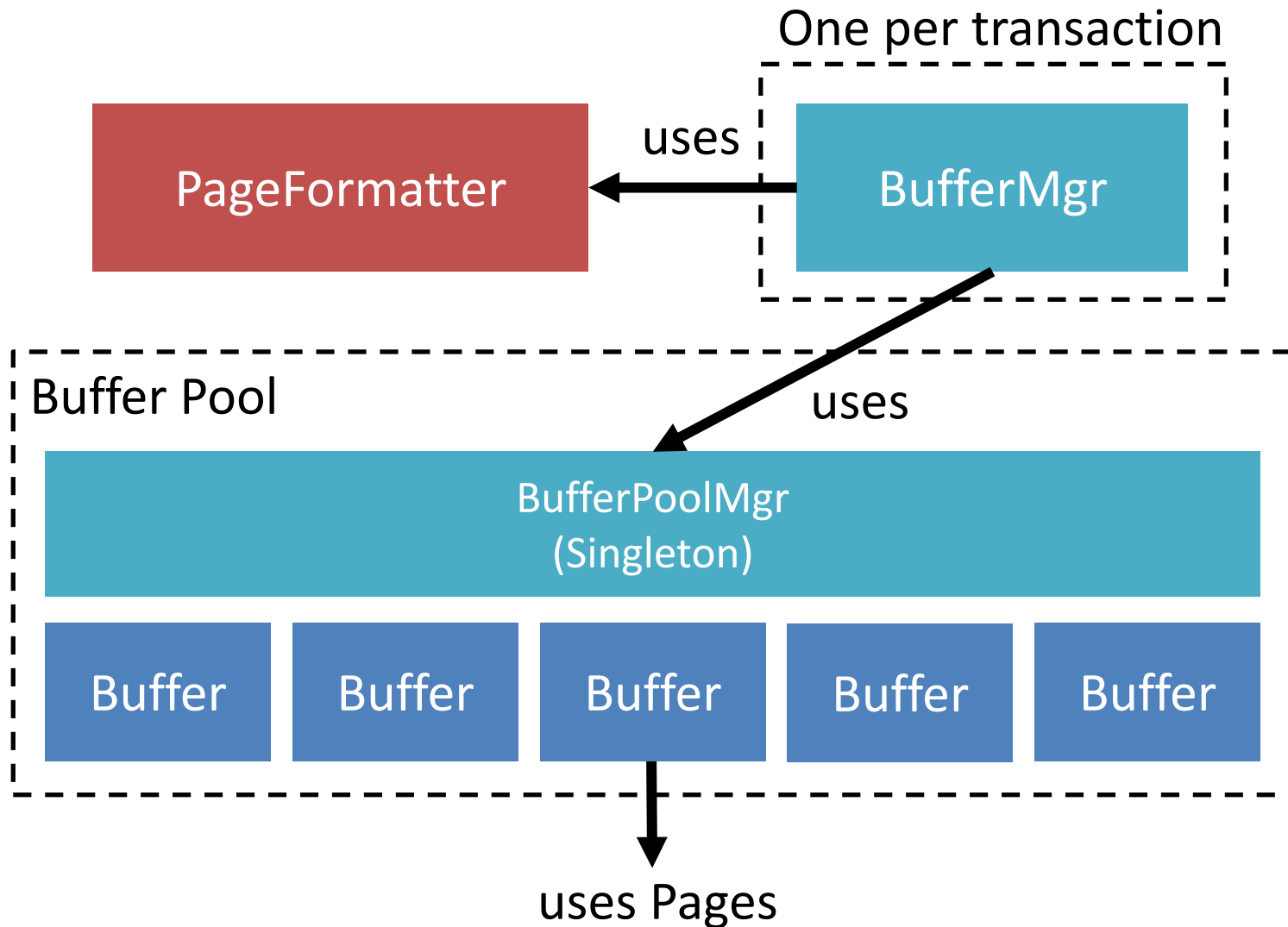
- File package
- Buffer package

# Where are we?

VanillaDB



# buffer Package





# BufferMgr vs. BufferPoolMgr

- Each transaction has its own BufferMgr, but there is only one BufferPoolMgr
- Responsibility
  - BufferPoolMgr manages the buffer pool
  - BufferMgr handles waiting for pinning and manages pinned buffers for each transaction

# BufferPoolMgr

| BufferPoolMgr  |
|--|
|  |
| <pre>~ BufferPoolMgr(numbuffs : int) &lt;&lt;synchronized&gt;&gt; ~ flushAll() &lt;&lt;synchronized&gt;&gt; ~ flushAll(txnum : long) &lt;&lt;synchronized&gt;&gt; ~ pin(blk : BlockId) : boolean &lt;&lt;synchronized&gt;&gt; ~ pinNew(filename : String, fmtr : PageFormatter) : Buffer &lt;&lt;synchronized&gt;&gt; ~ unpin(buffs : Buffer[]) &lt;&lt;synchronized&gt;&gt; ~ available() : int</pre> |

# BufferPoolMgr

- Singleton
- Finds a hit for a `pin()`
- Implements the **clock** replacement strategy
- The `pin()` ***returns null immediately*** if there's no candidate buffer
  - Then, the `BufferMgr` make the calling thread waiting and retrying later

# BufferMgr

BufferMgr : TransactionLifecycleListener

<<final>> # BUFFER\_POOL\_SIZE : int

- + BufferMgr()
- + onTxCommit(tx : Transaction)
- + onTxRollback(tx : Transaction)
- + onTxEndStatement(tx : Transaction)
- + pin(blk : BlockId)
- + pinNew(filename : String, fmtr : PageFormatter) : Buffer
- + unpin(buff : Buffer)
- + flushAll()
- + flushAll(txNum)
- + available() : int

# BufferMgr

- Created when constructing a transaction
- A `BufferMgr` manages the pinned buffers and the pinning counts of a transaction
- `BufferMgr.pin()` makes the calling thread to wait if there's no candidate buffer for replacement
  - How?

# Java `wait()` and `notifyAll()` Methods

- In Java, every object has a waiting list
  - `obj.wait(timeout)` puts the caller thread into the waiting list of `obj`
- The thread will be removed from the list and ready for execution in two conditions:
  - Another thread call `obj.notifyAll()`
  - Timeout elapsed

# Java `wait()` and `notifyAll()` Methods

- If...
  1. `obj.wait()` is surrounded by a synchronized block, and
  2. there are multiple threads in `obj`'s waiting list,
- Then when `notifyAll()` is called, **all** waiting threads will compete on the lock to enter the synchronized block
  - **No** FIFO guarantee which thread will be notified first, and which will acquire the lock first
  - Only one thread wins the lock, others **blocked** until the winner releases the lock

# BufferMgr

- `pin()`: if `BufferPoolMgr` returns null, put the current thread into `BufferPoolMgr`'s waiting list

```
buff = bufferPool.pin(blk);
while (buff == null && !waitingTooLong(timestamp)) {
    bufferPool.wait(MAX_TIME);
    buff = bufferPool.pin(blk);
}
```

- `unpin(buff)`: notify all threads in `BufferPoolMgr`'s waiting list
  - Only one thread will pin successfully due to the synchronization



```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

***Synchronize on the buffer pool (singleton)***

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

***Find the given block from the pinned buffers of this transaction***

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

***Pins the requested block***

***Add the buffer to the pinned list of this transaction***

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyALL();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

*If there was not any available buffer,  
make the thread waiting*

*The thread in the head of the list can pin*

*Wake up other thread again*

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

**Waiting too long? There might be deadlock.  
Re-pin all blocks**

```

public Buffer pin(BlockId blk) {
    synchronized (bufferPool) {
        PinnedBuffer pinnedBuff = pinnedBuffers.get(blk);
        if (pinnedBuff != null) {
            pinnedBuff.pinnedCount++;
            return pinnedBuff.buffer;
        }
        if (pinnedBuffers.size() == BUFFER_POOL_SIZE)
            throw new BufferAbortException();
        try {
            Buffer buff;
            long timestamp = System.currentTimeMillis();
            buff = bufferPool.pin(blk);
            if (buff == null) {
                waitingThreads.add(Thread.currentThread());
                while (buff == null && !waitingTooLong(timestamp)) {
                    bufferPool.wait(MAX_TIME);
                    if (waitingThreads.get(0).equals(Thread.currentThread()))
                        buff = bufferPool.pin(blk);
                }
                waitingThreads.remove(Thread.currentThread());
                bufferPool.notifyAll();
            }
            if (buff == null) {
                repin();
                buff = pin(blk);
            } else {
                pinnedBuffers.put(buff.block(), new PinnedBuffer(buff));
            }
            return buff;
        } catch (InterruptedException e) {
            throw new BufferAbortException();
        }
    }
}

```

**Self-deadlock: throw exception**

# Buffer

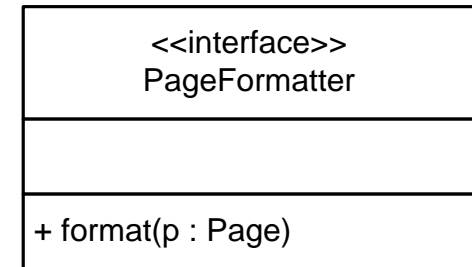
- Wraps a page and stores
  - ID of the holding block
  - Pin count
  - Modified information
  - Log information
- ***Supports WAL***
  - `setVal()` requires an LSN
    - Must be preceded by `LogMgr.append()`
  - `flush()` calls `LogMgr.flush(maxLsn)`
    - Called by `BufferMgr` upon swapping

| Buffer  |
|---|
|   |
| <pre>~ Buffer() &lt;&lt;synchronized&gt;&gt; + getVal(offset : int, type : Type) : Constant &lt;&lt;synchronized&gt;&gt; + setVal(offset : int, val : Constant , txnum : long, lsn : long) &lt;&lt;synchronized&gt;&gt; + block() : BlockId &lt;&lt;synchronized&gt;&gt; ~ flush() &lt;&lt;synchronized&gt;&gt; ~ pin() &lt;&lt;synchronized&gt;&gt; ~ unpin() &lt;&lt;synchronized&gt;&gt; ~ isPinned() : boolean &lt;&lt;synchronized&gt;&gt; ~ isModifiedBy(txNum : long) : boolean &lt;&lt;synchronized&gt;&gt; ~ assignToBlock(b : BlockId) &lt;&lt;synchronized&gt;&gt; ~ assignToNew (filename : String, fmtr : PageFormatter)</pre> |



# PageFormatter

- The `pinNew(fmtr)` method of `BufferMgr` appends a new block to a file
- `PageFormatter` initializes the block
  - To be extended in packages (`storage.record` and `storage.index.btree`) where the semantics of records are defined



```
class ZeroIntFormatter implements PageFormatter {  
    public void format(Page p) {  
        Constant zero = new IntegerConstant(0);  
        int recsize = Page.size(zero);  
        for (int i = 0; i + recsize <= Page.BLOCK_SIZE; i += recsize)  
            p.setVal(i, zero);  
    }  
}
```