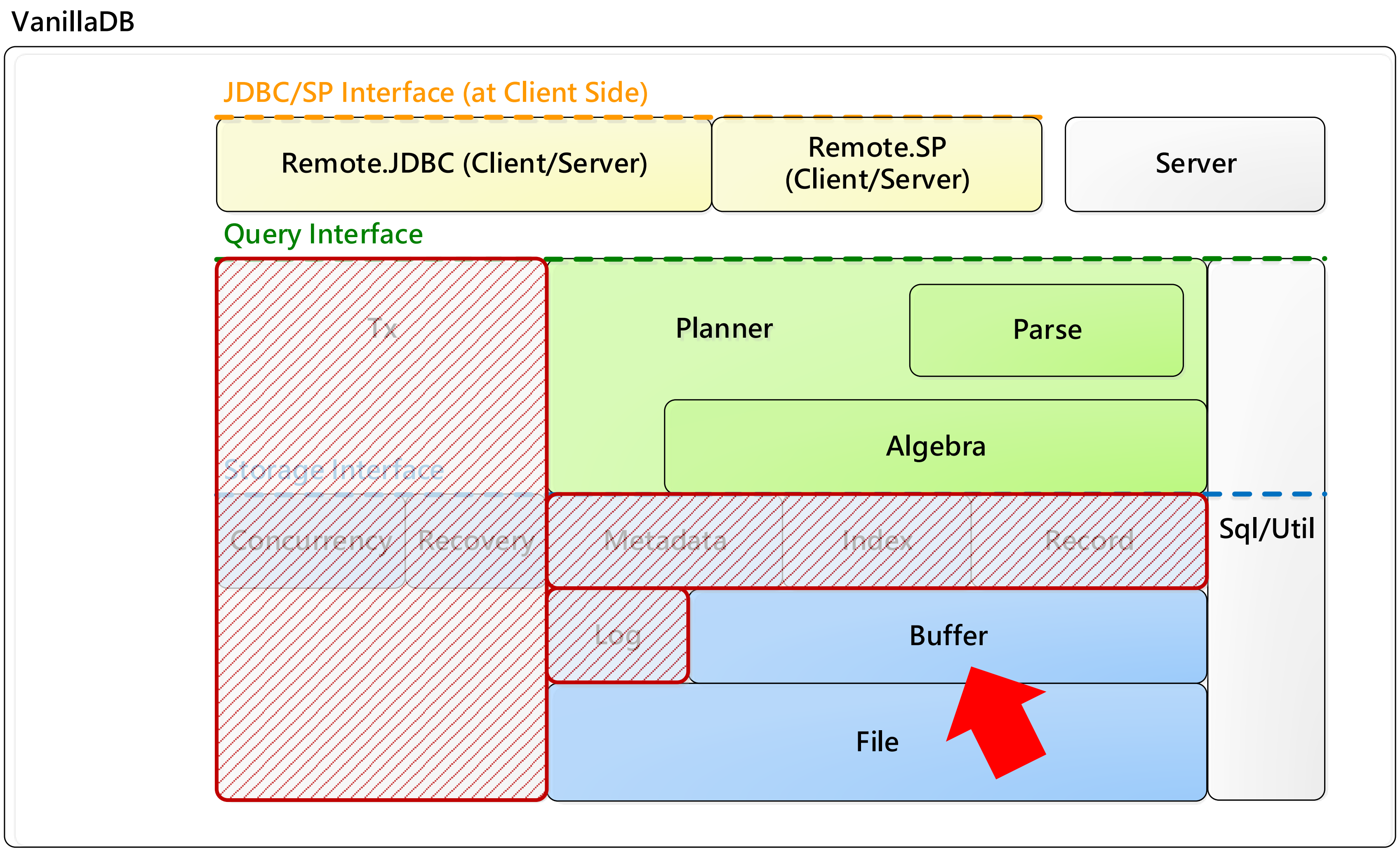
VanillaCore Walkthrough Part 4

Introduction to Databases

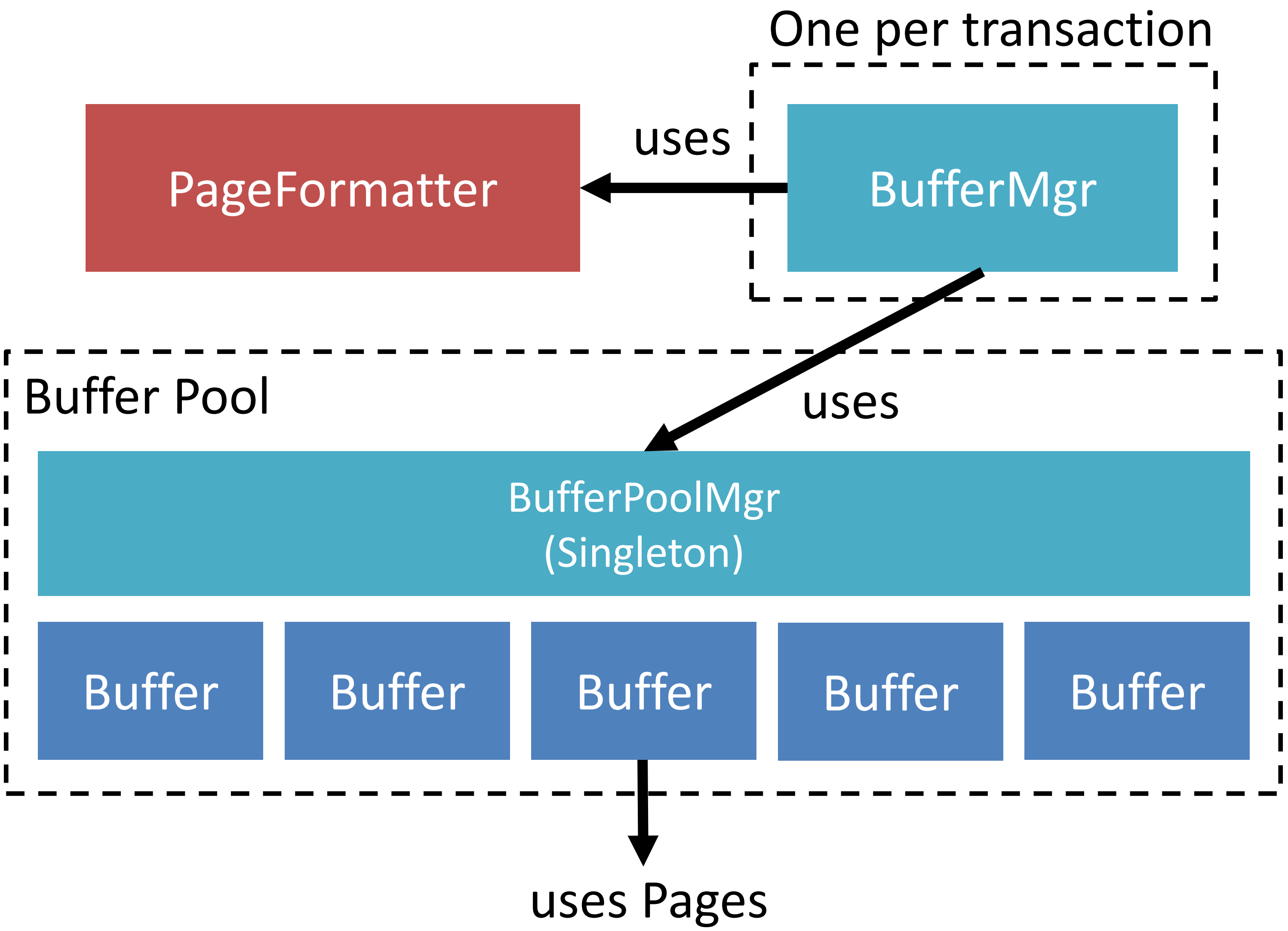
DataLab

CS, NTHU

Today's Focus



`buffer` Package



Functionality

- Main Components
  - `Buffer`: a memory space for caching a block
  - `BufferPoolMgr`: manages the buffer pool
  - `BufferMgr`: provides the access to buffers and manages the pinned buffers for each transaction
    - A transaction waits here if it could not pin any buffer.
  - `PageFormatter`: formats a fresh block

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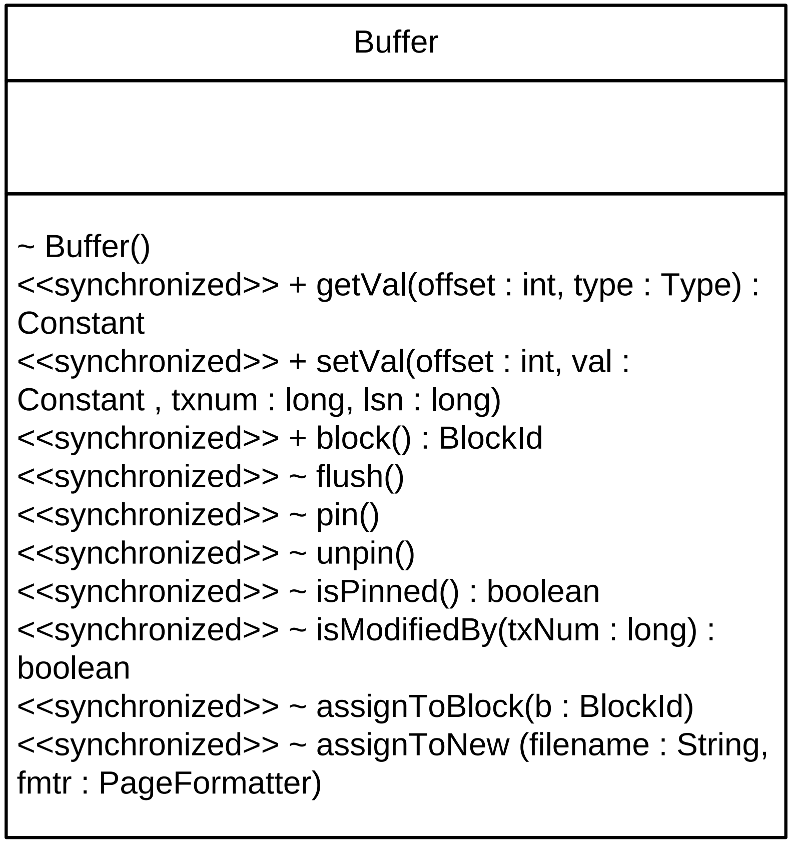
Buffer

- 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)`



```
Buffer

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

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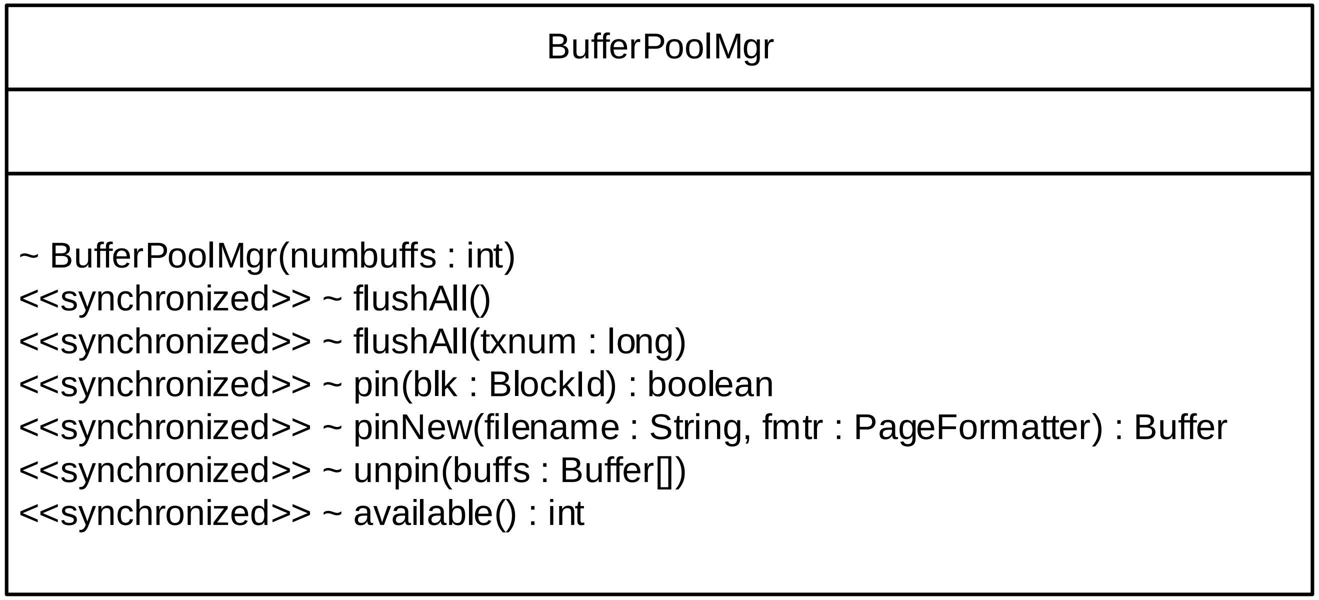
BufferPoolMgr



```
BufferPoolMgr

~ BufferPoolMgr(numbuffs : int)
<<synchronized>> ~ flushAll()
<<synchronized>> ~ flushAll(txnum : long)
<<synchronized>> ~ pin(blk : BlockId) : boolean
<<synchronized>> ~ pinNew(filename : String, fmtr : PageFormatter) : Buffer
<<synchronized>> ~ unpin(buffs : Buffer[])
<<synchronized>> ~ available() : int
```

`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

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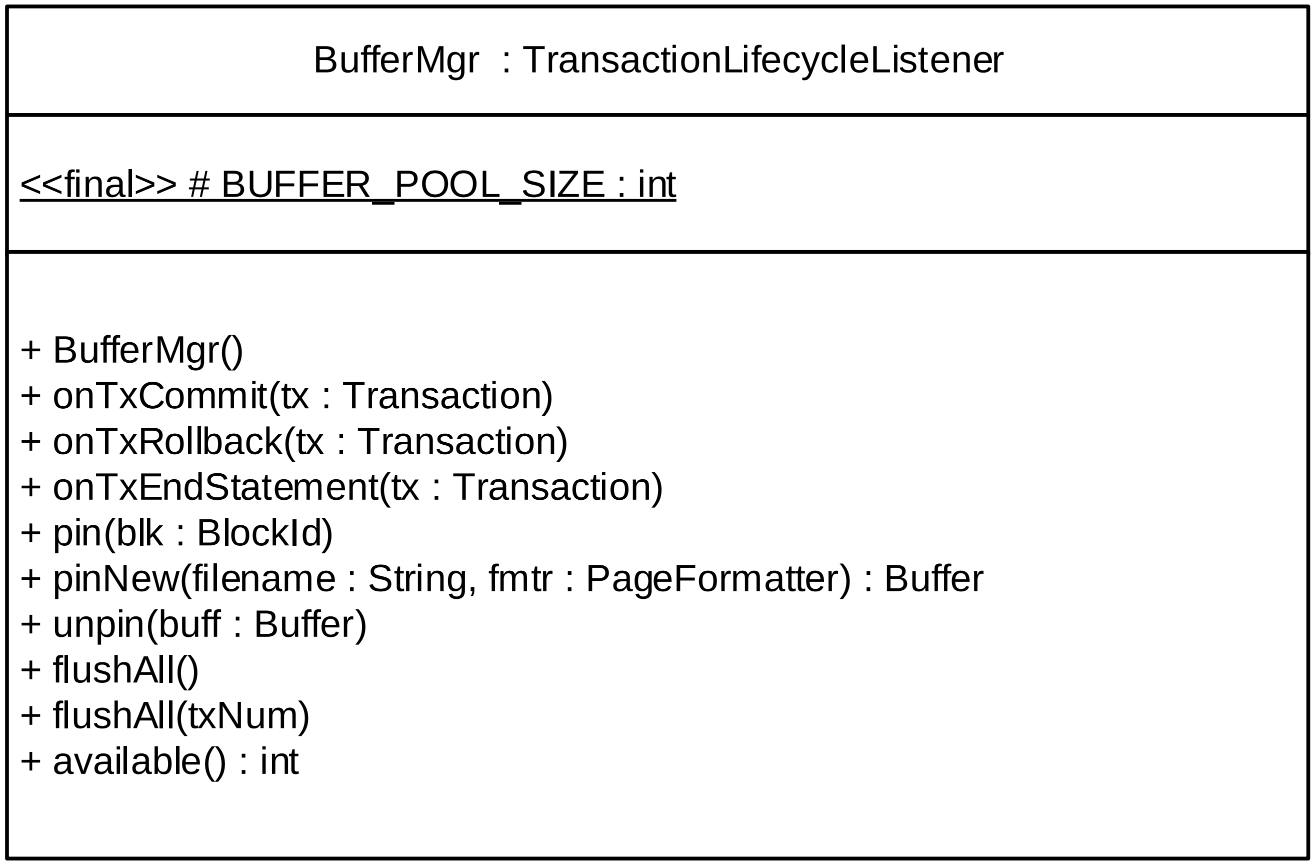
BufferMgr



```
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

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

`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

```
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)

```java
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();
        }
    }
}
```

Waitting 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

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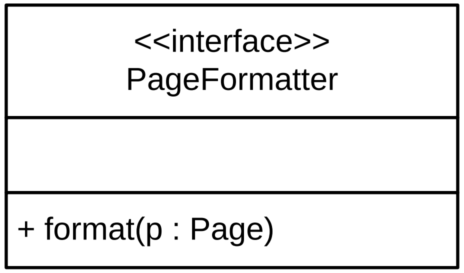
PageFormatter

- 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



```java
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);
    }
}
```