Lab 4 Details

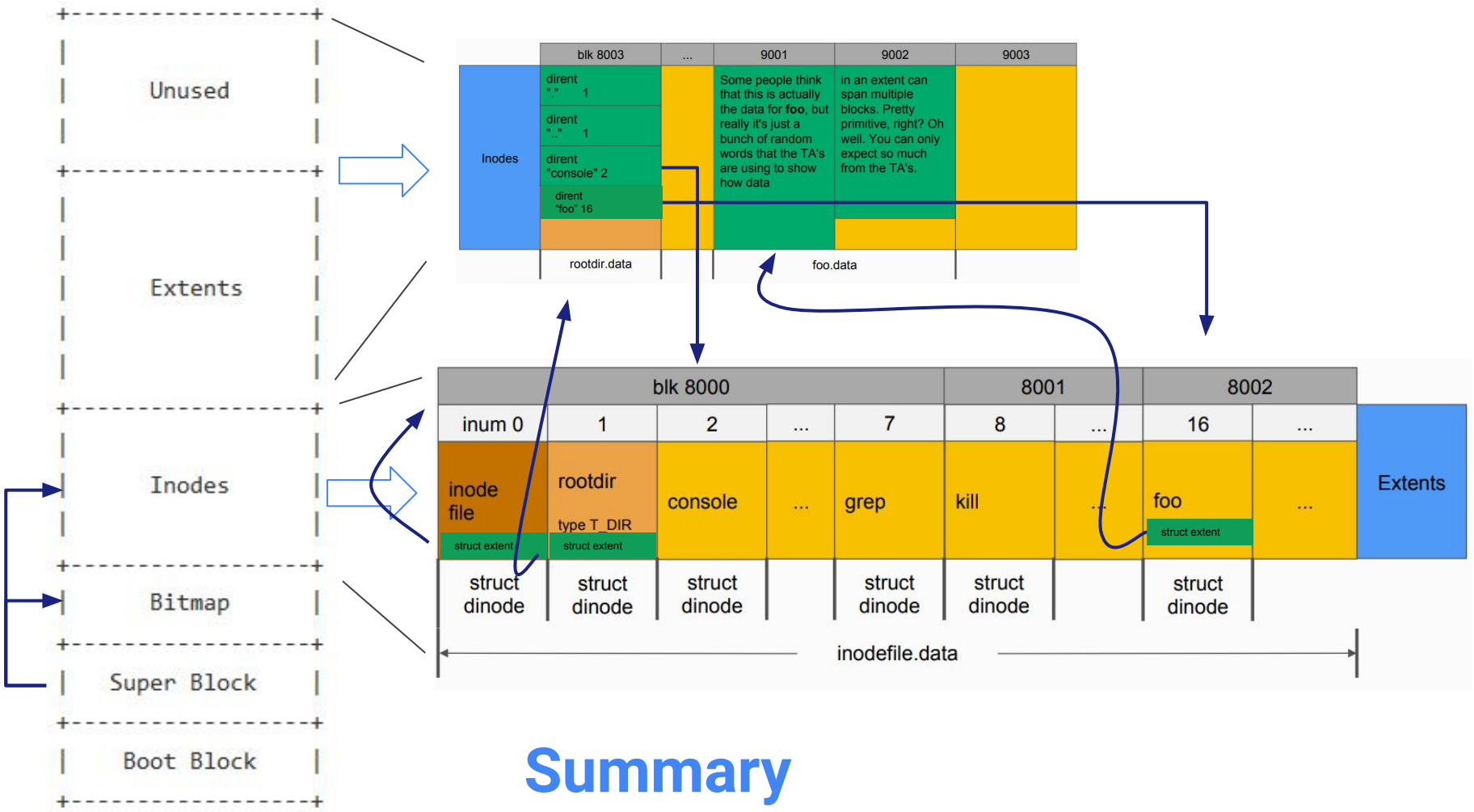
Even more file stuff

Admin

- Lab 4 due on the last day of instruction
  - Design doc feedback should be back by end of next weekend

Late Policy TBD

Part A: File Operations

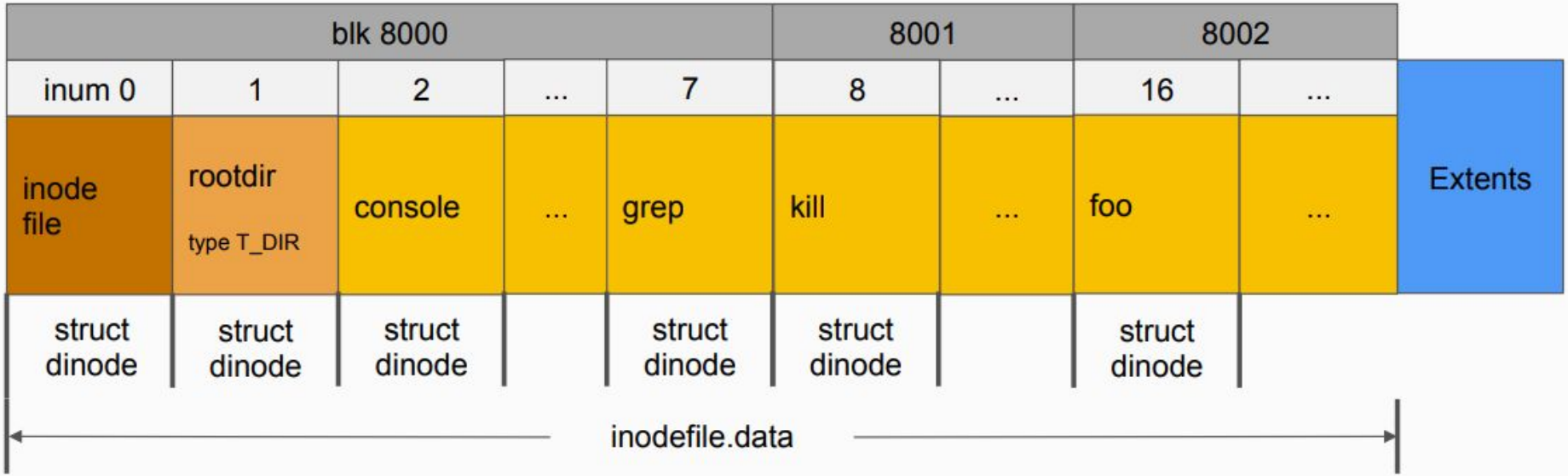

Unused
Extents
Inodes
Bitmap
Super Block
Boot Block
blk 8003
...
9001
9002
9003
Inodes
dirent "." 1
dirent ".." 1
dirent "console" 2
dirent "foo" 16
Some people think that this is actually the data for foo, but really it's just a bunch of random words that the TA's are using to show how data
in an extent can span multiple blocks. Pretty primitive, right? Oh well. You can only expect so much from the TA's.
rootdir.data
foo.data
blk 8000
8001
8002
inum 0
1
2
...
7
8
...
16
...
inode file
rootdir
type T_DIR
console
...
grep
kill
...
foo
...
Extents
struct extent
struct extent
struct extent
struct dinode
struct dinode
struct dinode
struct dinode
struct dinode
struct dinode
inodefile.data

Summary

Inodefile

- The inodefile is the “inodes” section on disk, which stores the table of inodes (struct dinode)
  - Reading from and writing to inodefile is just like reading/writing for a normal file
- 0th inode is the inodefile itself
  - Data field in 0th inode corresponds to inodes region
- 1st inode is the root directory
  - Data field is array of directory entries (struct dirent)
- **icache.inodefile** points to the inode file

Inodefile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icache

- Disk operation are slow
  - Thus, we have a cache of inodes
- icache.inodefile is initialized at system startup
- icache.inode is an in-memory cache of most-recently-used inodes
  - They are not in order! Use iget to search the cache and irelease to release the cache!
- Difference between inode and dinode
  - In memory vs on disk
  - Need to synchronize them: read_dinode (provided, used in locki) move data from disk to memory. write_dinode move data from memory to disk (not provided)

```
struct {
 struct spinlock lock;
 struct inode inode[NINODE];
 struct inode inodefile;
} icache;
```

Helpful functions

iget: create a cache entry for the in-memory copy of the inode, but the entry is empty (doesn't synchronize with dinode)

locki: copy information from dinode to the in-memory inode cache

read_dinode: read the dinode from the disk

readi/writei: the inodefile, root directory and files are all abstracted as inode! You can reuse the code for readi/writei to read/write their extents.

read_dinode

```
// Reads the dinode with the passed inum from the inode file.
// Threadsafe, will acquire sleeplock on inodefile inode if not held.
void read_dinode(uint inum, struct dinode *dip) {
    int holding_inodefile_lock = holdingsleep(&icache.inodefile.lock);
    if (!holding_inodefile_lock)
        locki(&icache.inodefile);

    readi(&icache.inodefile, (char *)dip, INODEOFF(inum), sizeof(*dip));

    if (!holding_inodefile_lock)
        unlocki(&icache.inodefile);

}
```

```
// offset of inode in inodefile
#define INODEOFF(inum) ((inum) * sizeof(struct dinode))
```

- What does the function do?
  - Reads in struct dinode at index `inum` from inodefile
- Having a similar write_dinode() can be helpful (not provided in starter code)
  - When should we write dinode?

Block Operations

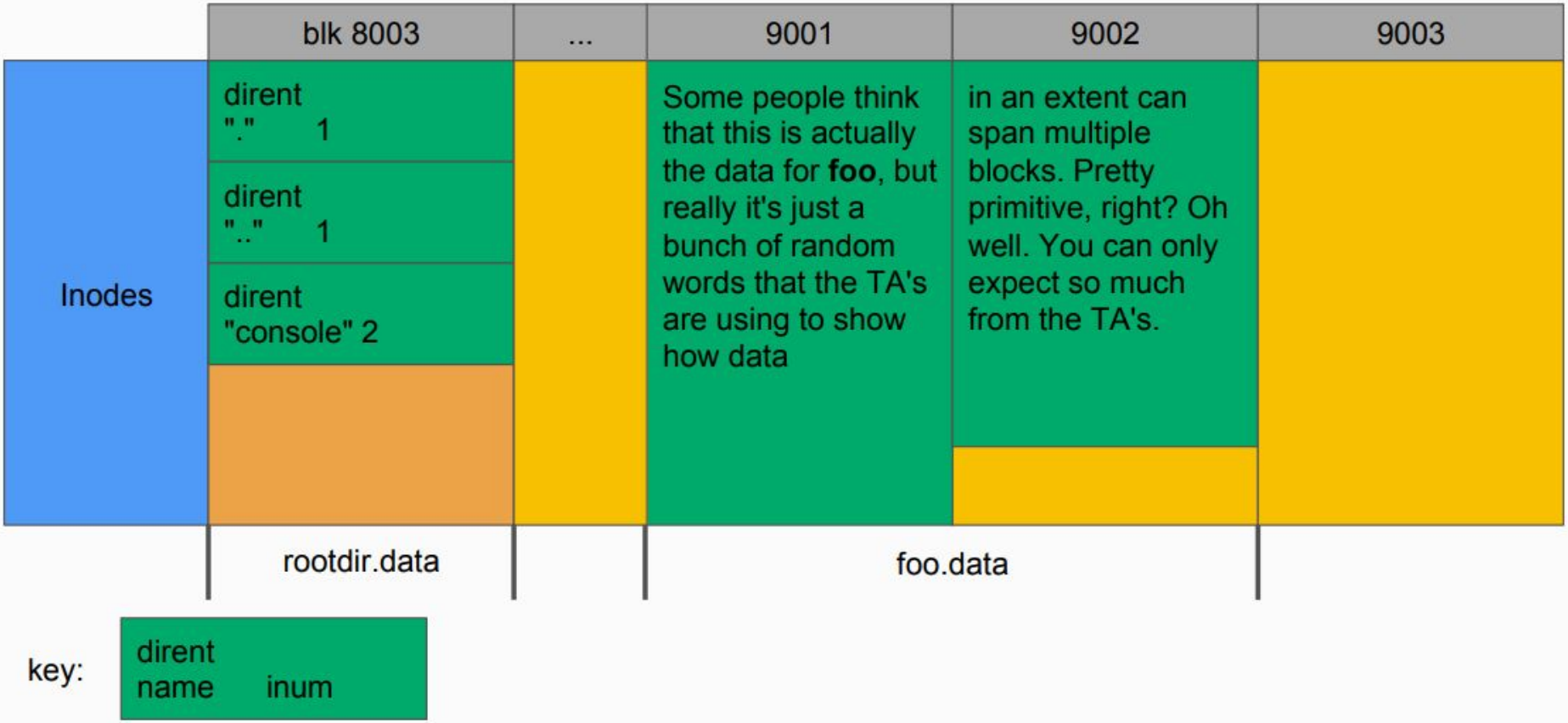
- We also have a cache for blocks
- bread: move data from disk to memory. Search the cache first and then read the block if cache is not found
- bwrite: move data from memory (cache) back to disk.
- brelease: release the cache

Extents

- Extents region - where the actual data for files in the filesystem lives (excluding the initial inode file)

- Extent - sequence of contiguous blocks of disk
  - When allocating an extent for a file, all blocks in the extent should be marked used in the bitmap even if no data is written yet
    - “Reserving” contiguous blocks for file to use

Extents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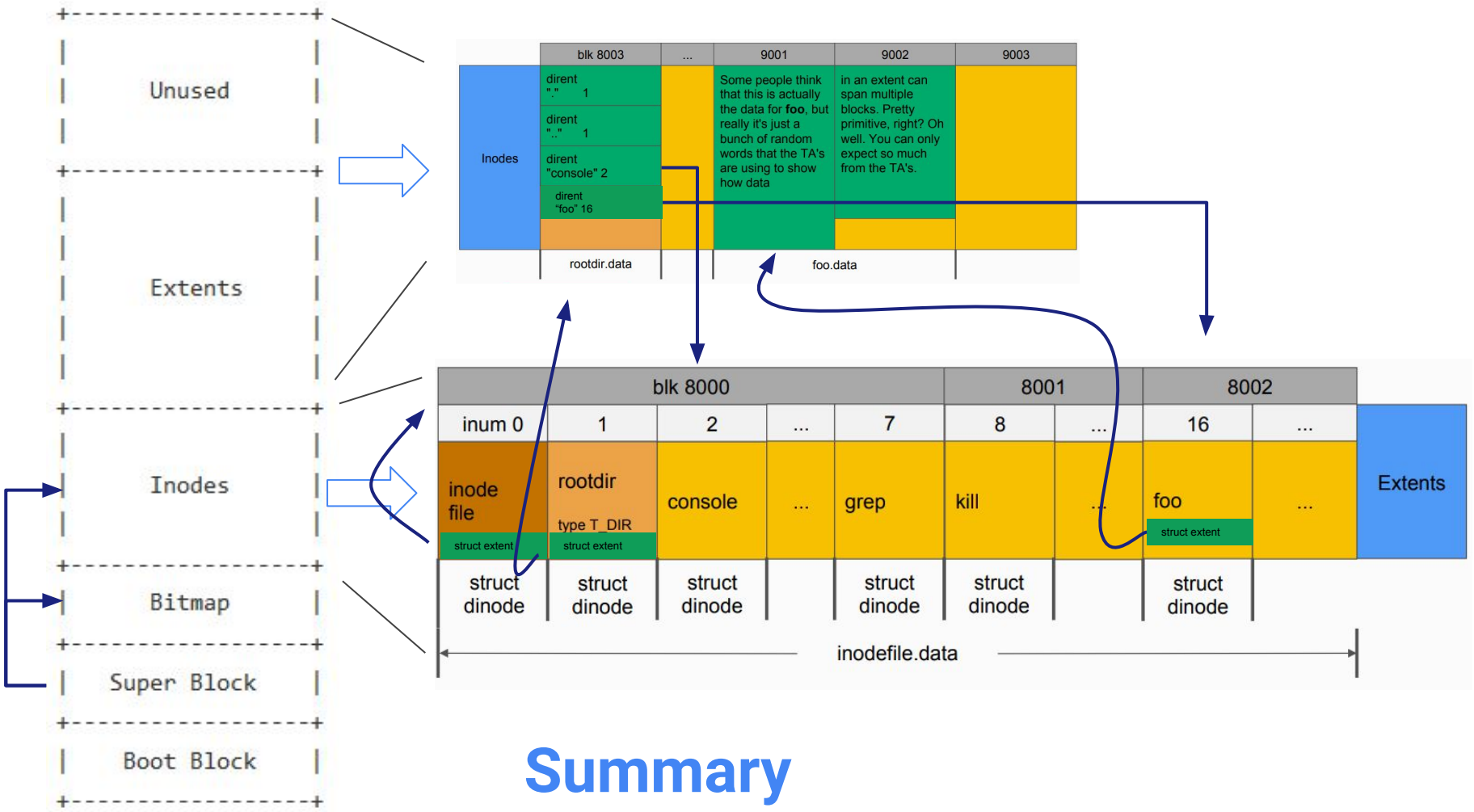
foo.data
key:
dirent
name
inum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Summary

Bitmap

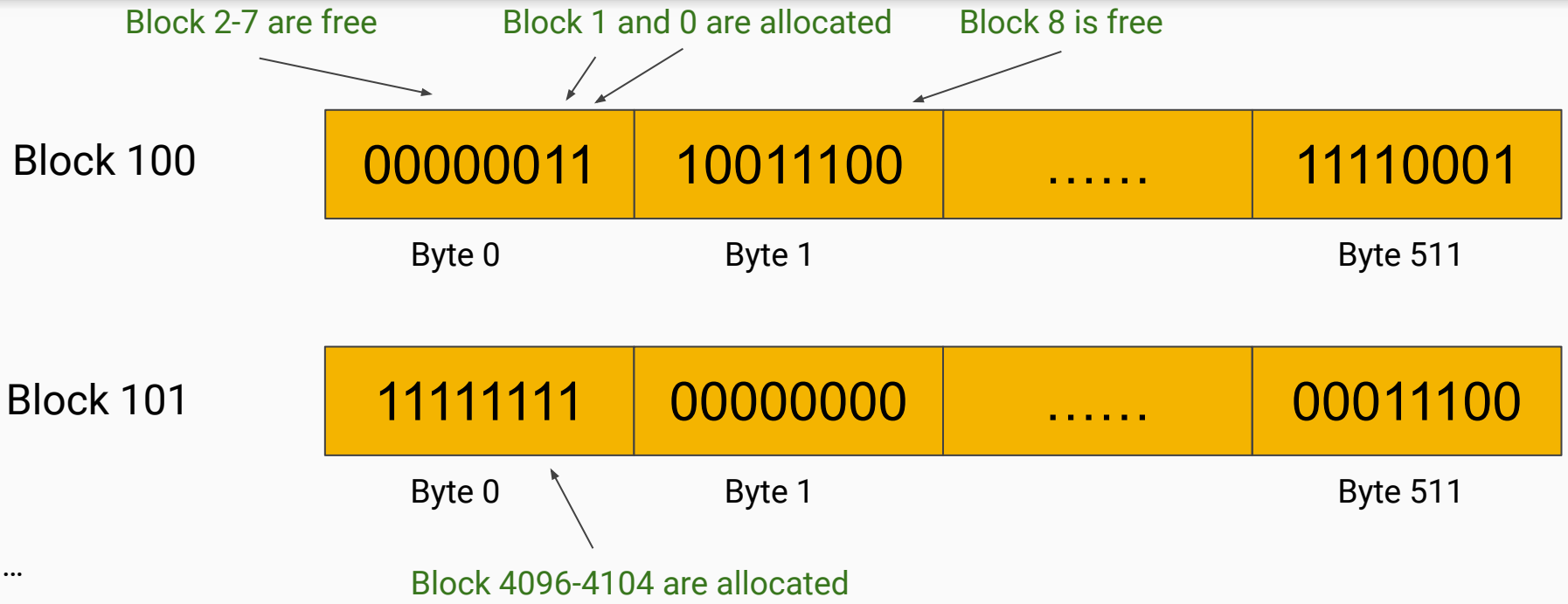
- Each block contains 512 bytes
  - Each block in bitmap represents 512 * 8 = 4096 blocks
    - (i.e., block at sb.bmapstart -> blocks 0-4095 , sb.bmapstart + 1 -> 4096-8191, etc.
  - Need to use bitmasking to mark blocks in bitmap
- Some useful macros
  - BBLOCK(b, sb) -> block number in bitmap containing b
- Trick: you can check 8 bits together as a byte

```
// Bitmap bits per block
#define BPB (BSIZE * 8)

// Block of free map containing bit for block b
#define BBLOCK(b, sb) ((b) / BPB + (sb).bmapstart)
```

Bitmap Example

Assume sb.bmapstart = 100



Part B: Crash Safety

Log API

- The spec recommends designing an API for yourself for log operations:
  - **log_begin_tx()**: (optional) begin the process of a transaction
  - **log_write()**: wrapper function around normal block writes
  - **log_commit_tx()**: complete a transaction and write out the commit block
  - **log_recover()**: log playback when the system reboots and needs to check the log for disk consistency
    - Where/when should this be called? (Hint: inspect **kernel/fs.c**)

What should log_write() do differently?

- log_write() intended to be a wrapper function for bwrite() operations
- Instead of writing the block to its location on disk, we want to:
  - write the block information to our log region
  - keep the block in memory until transaction successfully commits (performance optimization)

- To write to a block but *keep changes in memory*
  - Look into setting B_DIRTY bit for that block when calling bwrite - this will ensure the changes are are not immediately flushed to disk

What should log_write() do differently?

- Once all block writes in transaction have called log_write(), log_commit_tx() will be called

- Commit
  - Flush commit block to disk
  - Flush dirty blocks from previous log_writes to their actual location on disk
    - How?
  - Reset commit flag

Questions?

Good luck on Lab 4!