CSE 333
Section 7

HW3 Overview, Casting

UNIVERSITY *of* WASHINGTON

Logistics

Friday, Feb 26:

HW3 @ 11 pm

Section Plan

- Casting
- HW 3 Overview

Casting in C++

Casting in C

- Types are enforced unless converted
- **Casting** is a conversion between data types
- Can cast with anything in C!

Implicit Casting

```
double a = 10.5;
int b = a;
```

Explicit Casting

```
double a = 10.5;
int b = (int) a;
```

Casting in C++

Four different casts that are more explicit and help prevent unintended errors:

1. `static_cast<to_type>(expression)`
2. `dynamic_cast<to_type>(expression)`
3. `const_cast<to_type>(expression)`
4. `reinterpret_cast<to_type>(expression)`

When programming in C++, you should use these casts!

Static Cast

```
static_cast<to_type>(expression)
```

Used to:

1) Convert pointers of *related* types

```
Base* b = static_cast<Base*>(new Derived);
```

- compiler error if types aren't related

2) Non-pointer conversion

```
int qt = static_cast<int>(3.14);
```

Static Cast

```
static_cast<to_type>(expression)
```

[!] Be careful when *casting down*:

```
Derived* d = static_cast<Derived*>(new Base);
d->y = 5;
```

- compiler will let you do this
- dangerous if you want to do things defined in **Derived**, but not in **Base**!

Dynamic Cast

```
dynamic_cast<to_type>(expression)
```

Used to:

1) Convert pointers of *related* types

```
Base* b = dynamic_cast<Base*>(new Derived);
```

- *compiler* error if types aren't related
- at *runtime*, returns **nullptr** if it is actually an unsafe downwards cast:

```
Derived* d = dynamic_cast<Derived*>(new Base);
```

Const Cast

```
const_cast<to_type>(expression)
```

Used to:

1) Add or remove const-ness

```
const int x = 5;
const int *ro_ptr = &x
int *ptr = const_cast<int*>(ro_ptr);
```

Reinterpret Cast

```
reinterpret_cast<to_type>(expression)
```

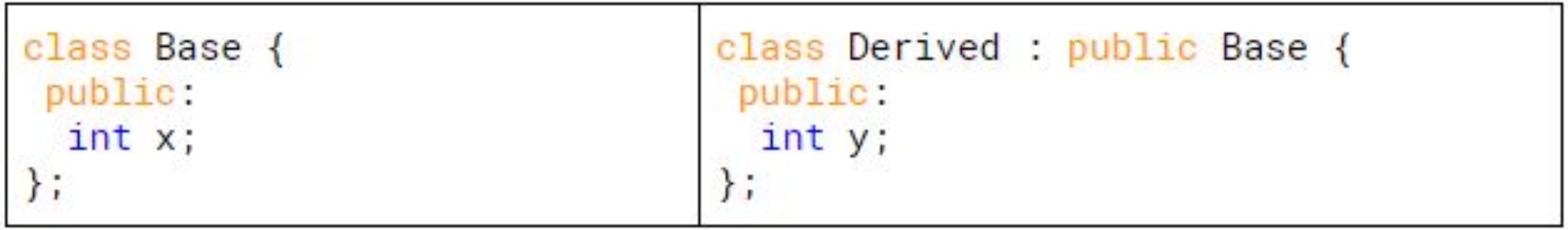
Used to:

1) Cast between *incompatible* types

    ```
    int* ptr = 0xDEADBEEF;
    int64_t x = reinterpret_cast<int64_t>(ptr);
    ```

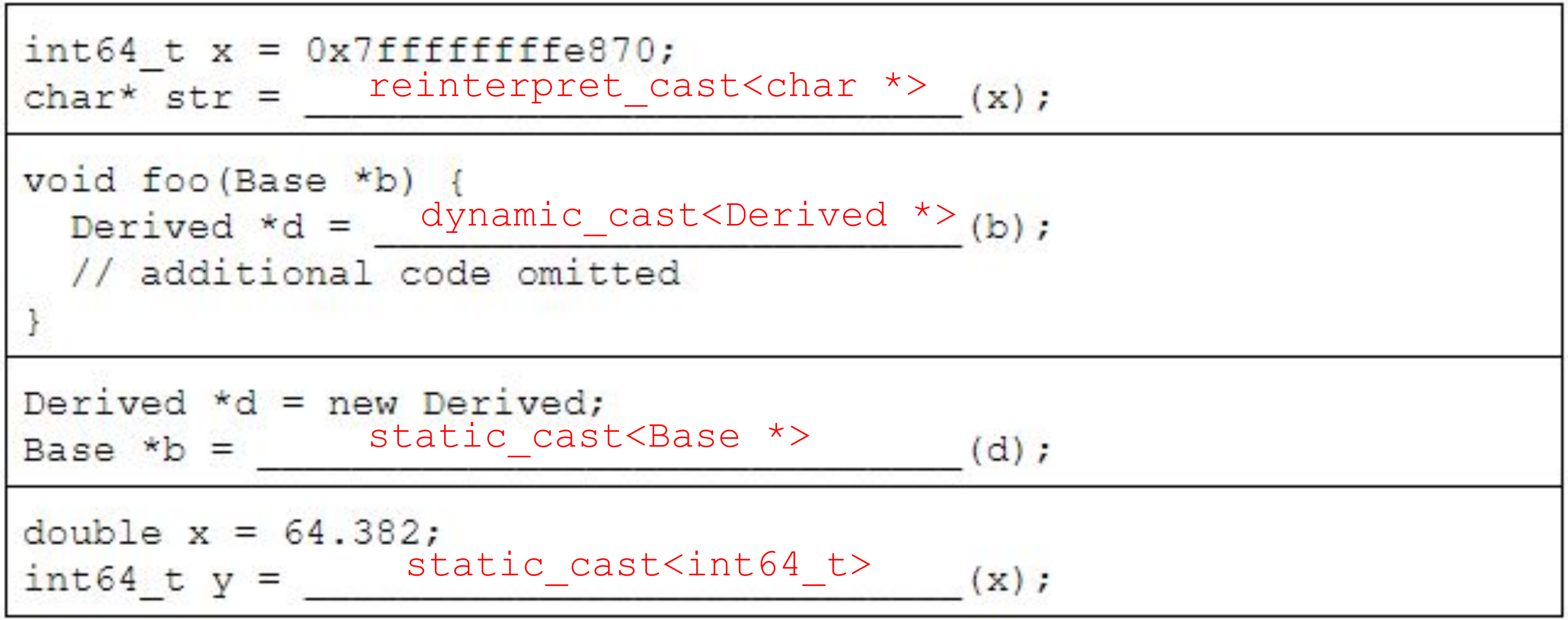
    - types must be of same size
    - does not do float-integer conversions

Exercise 1



```
class Base {
 public:
  int x;
};
```

```
class Derived : public Base {
 public:
  int y;
};
```



```
int64_t x = 0x7fffffffe870;
char* str = ____reinterpret_cast<char *>____(x);
```

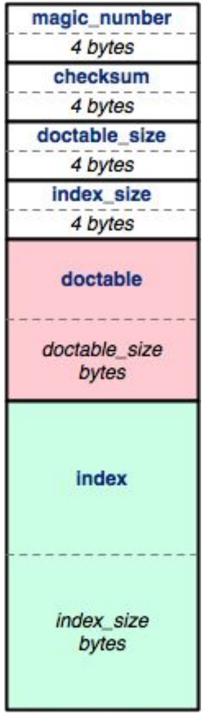
```
void foo(Base *b) {
  Derived *d = ____dynamic_cast<Derived *>____(b);
  // additional code omitted
}
```

```
Derived *d = new Derived;
Base *b = ____static_cast<Base *>____(d);
```

```
double x = 64.382;
int64_t y = ____static_cast<int64_t>____(x);
```

HW 3 Overview!

Index File



magic_number

4 bytes

checksum

4 bytes

doctable_size

4 bytes

index_size

4 bytes

doctable

doctable_size bytes

index

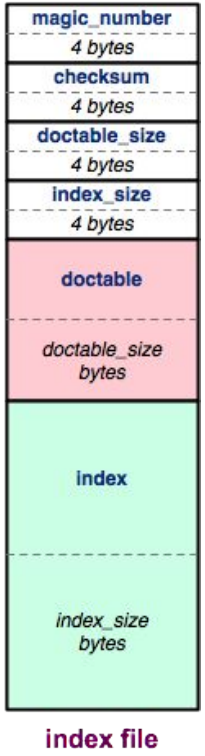
index_size bytes

index file

Crawling a file tree in HW2 takes a long time.

To save time, write the completed DocTable and MemIndex to a File!

Index File Components

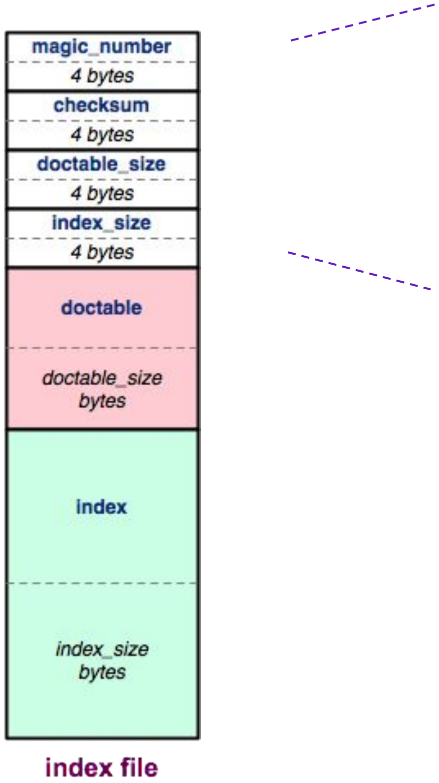


Header (metadata)

DocTable

MemIndex

Index File Header

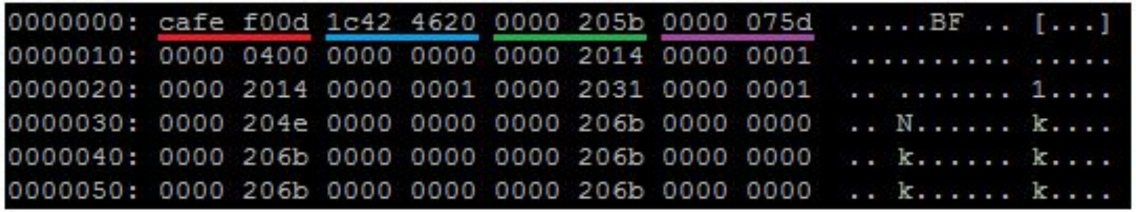


- magic_number: 0xCAFEF00D
- checksum: mathematical signature
- doctable_size: in bytes
- index_size: in bytes

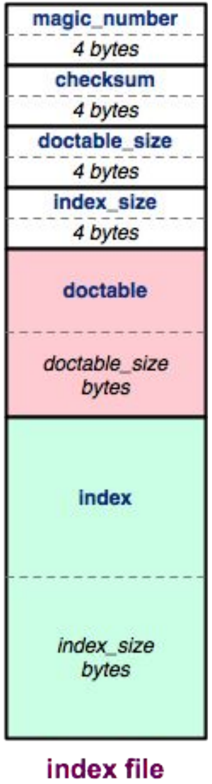
Index File Header - HEX

1. Find a hex editor/viewer of your choice

   - xxd <indexfile>
   - hexdump –vC <indexfile>



```
0000000: cafe f00d 1c42 4620 0000 205b 0000 075d  .....BF .. [...]
0000010: 0000 0400 0000 0000 0000 2014 0000 0001  ........... .....
0000020: 0000 2014 0000 0001 0000 2031 0000 0001  .. ........ 1....
0000030: 0000 204e 0000 0000 0000 206b 0000 0000  .. N....... k....
0000040: 0000 206b 0000 0000 0000 206b 0000 0000  .. k....... k....
0000050: 0000 206b 0000 0000 0000 206b 0000 0000  .. k....... k....
```



The header:

Magic word Checksum Doctable size Index size

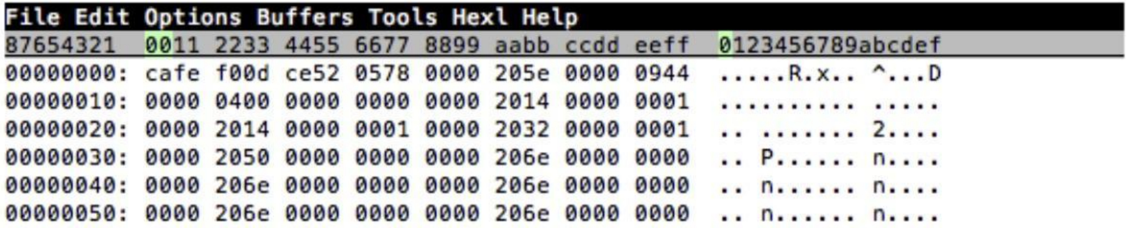
man xxd
man hexdump

Byte Ordering and Endianness

- Network (Disk) Byte Order (Big Endian)
  - The most significant byte is stored in the highest address
- Host byte order
  - Might be big or little endian, depending on the hardware
- To convert between orderings, we can use
  - uint32_t htonl (uint32_t hostlong);   // host to network
  - uint32_t ntohl (uint32_t hostlong);   // network to host
- Pro-tip:
  The structs in HW3 have toDiskFormat() and toHostFormat() functions that will convert endianness for you.

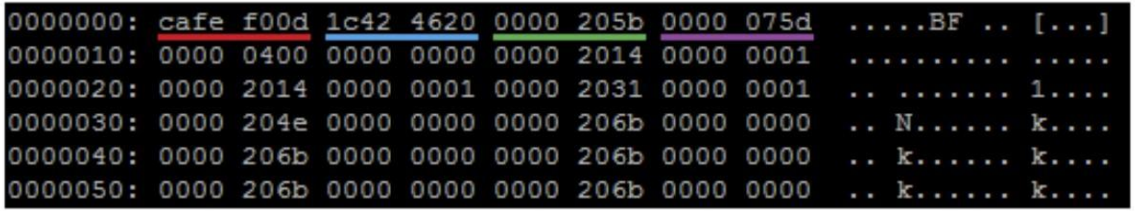
Hex View

- emacs “M-x hexl-mode”



```
87654321  0011 2233 4455 6677 8899 aabb ccdd eeff  0123456789abcdef
00000000: cafe f00d ce52 0578 0000 205e 0000 0944  .....R.x.. ^...D
00000010: 0000 0400 0000 0000 0000 2014 0000 0001  .......... .....
00000020: 0000 2014 0000 0001 0000 2032 0000 0001  .. ....... 2....
00000030: 0000 2050 0000 0000 0000 206e 0000 0000  .. P...... n....
00000040: 0000 206e 0000 0000 0000 206e 0000 0000  .. n...... n....
00000050: 0000 206e 0000 0000 0000 206e 0000 0000  .. n...... n....
```

- vim “:%!xxd”



```
0000000: cafe f00d 1c42 4620 0000 205b 0000 075d  .....BF .. [...]
0000010: 0000 0400 0000 0000 0000 2014 0000 0001  .......... .....
0000020: 0000 2014 0000 0001 0000 2031 0000 0001  .. ....... 1....
0000030: 0000 204e 0000 0000 0000 206b 0000 0000  .. N...... k....
0000040: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....
0000050: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....
```

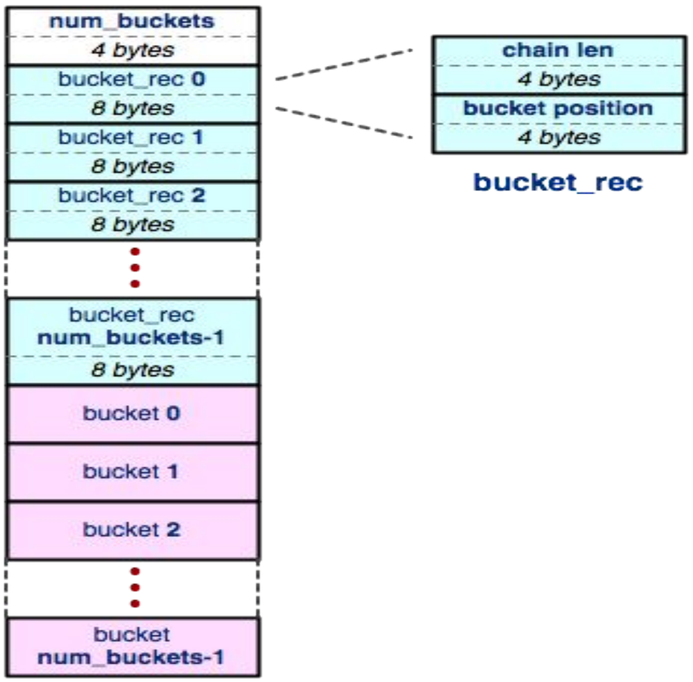
DocTable & MemIndex

- At their core, both DocTable & MemIndex are HashTables.
- Lets first look at how we write a HashTable.

HashTable

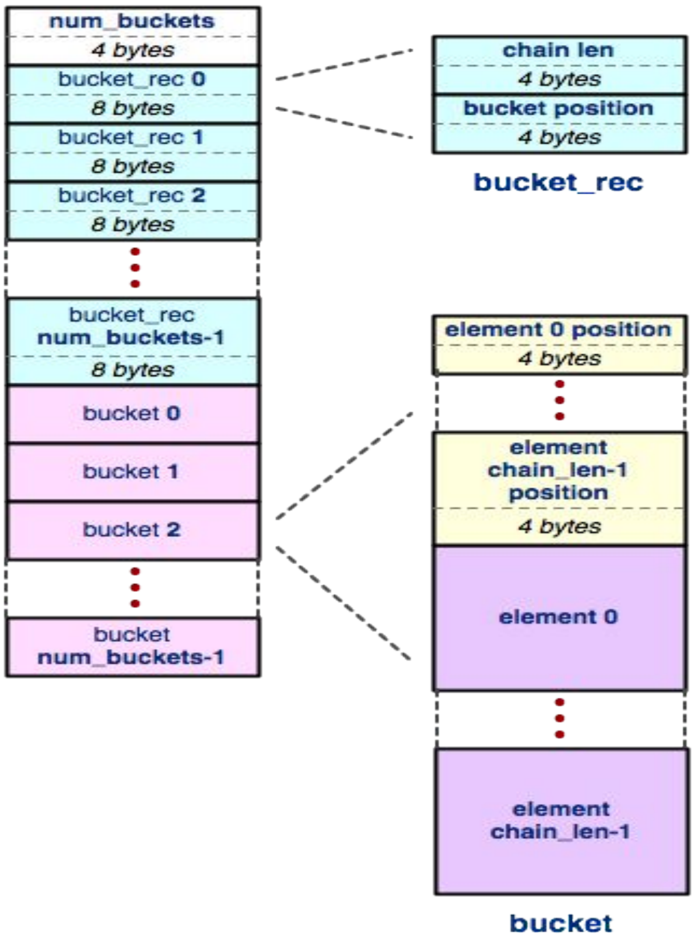
- HashTable can have varying amount of buckets, so start with num_buckets.

- Buckets can be of varying lengths. To know the offset, we store some bucket records.



Buckets

- A bucket is a list that contains elements in the table. Offset to a bucket is found in a bucket record.
- Elements can be of various sizes, so we need to store element positions to know where each element is.

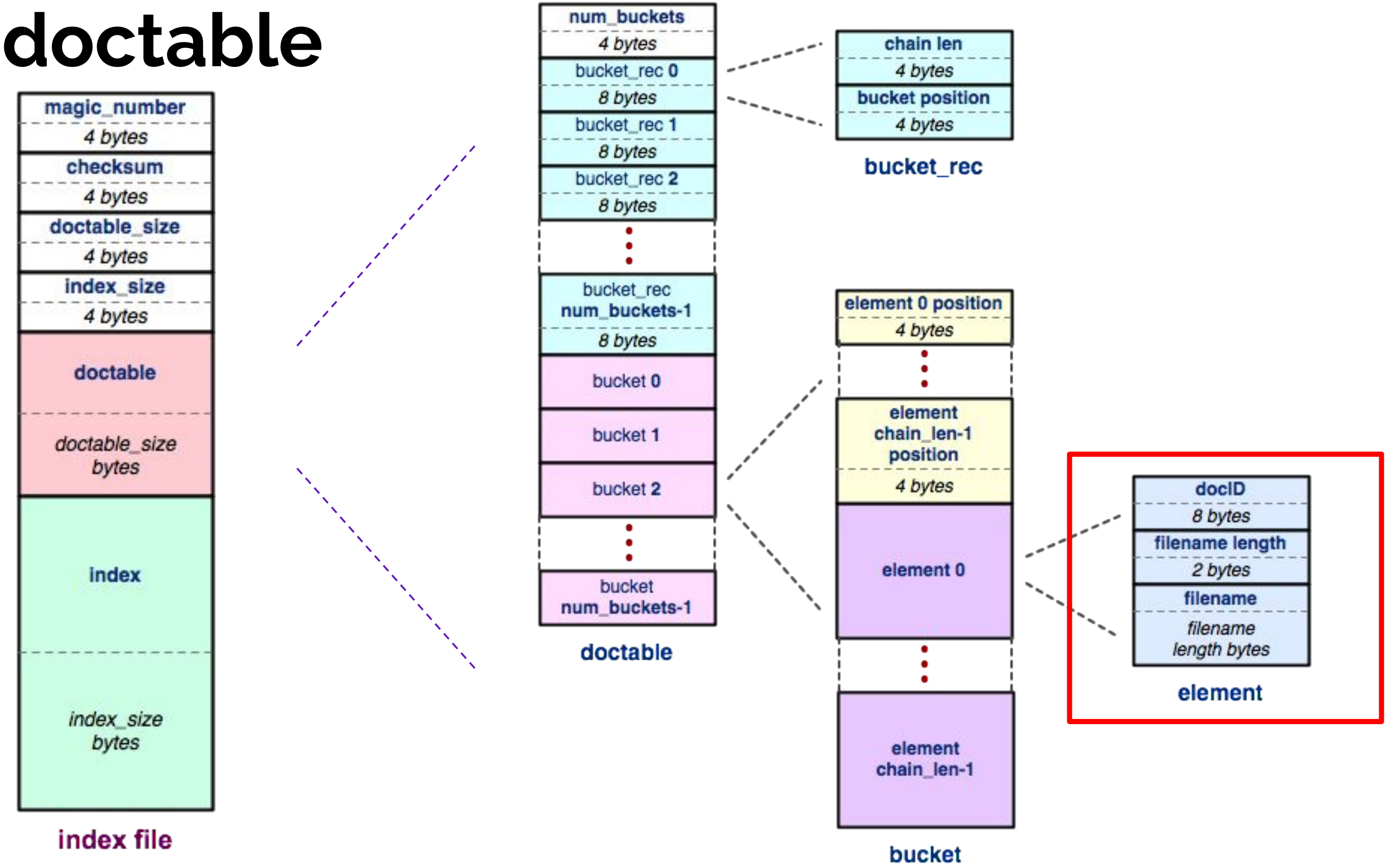


DocTable & MemIndex

- At their core, both DocTable & MemIndex are HashTables.

- The difference between DocTable and MemIndex is entirely what type of element is stored in them.

doctable



magic_number
4 bytes
checksum
4 bytes
doctable_size
4 bytes
index_size
4 bytes
doctable
doctable_size bytes
index
index_size bytes
index file

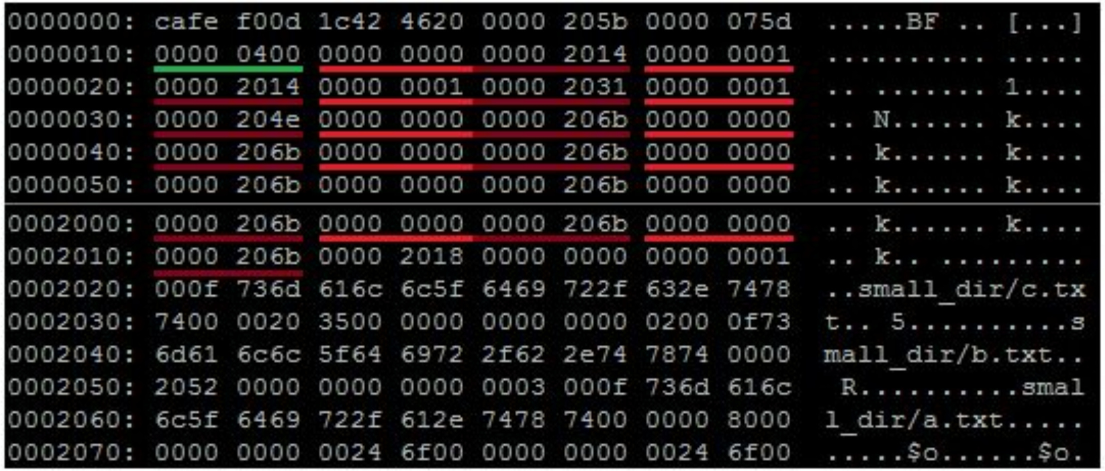
num_buckets
4 bytes
bucket_rec 0
8 bytes
bucket_rec 1
8 bytes
bucket_rec 2
8 bytes
bucket_rec num_buckets-1
8 bytes
bucket 0
bucket 1
bucket 2
bucket num_buckets-1
doctable

chain len
4 bytes
bucket position
4 bytes
bucket_rec

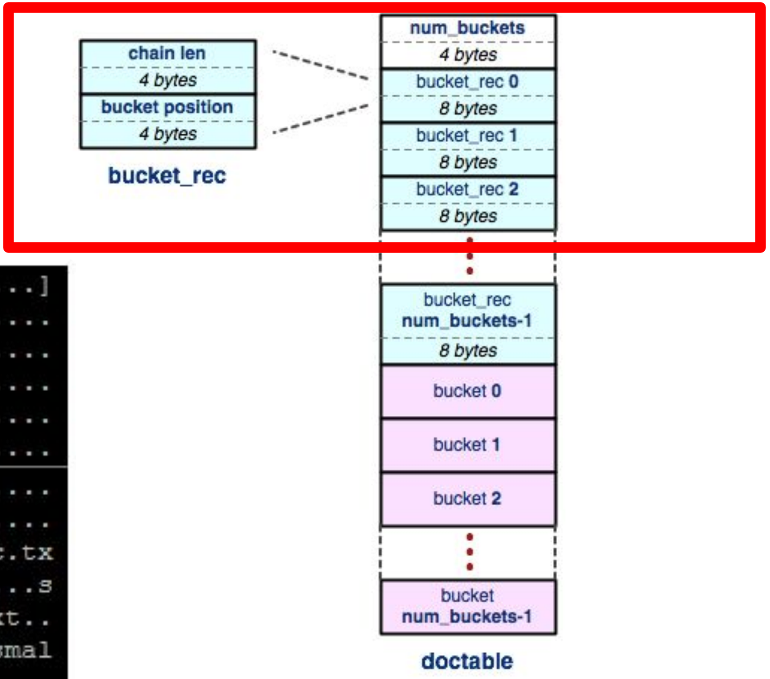
element 0 position
4 bytes
element chain_len-1 position
4 bytes
element 0
element chain_len-1
bucket

docID
8 bytes
filename length
2 bytes
filename
filename length bytes
element

DocTable (Hex)



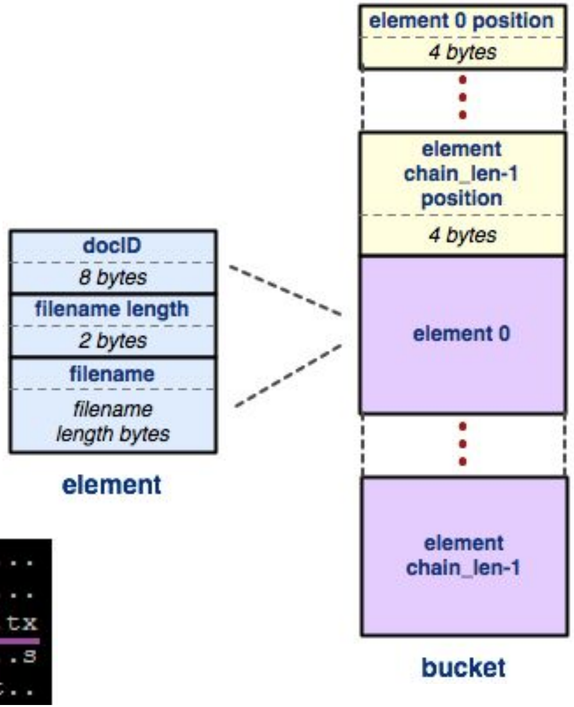
```
0000000: cafe f00d 1c42 4620 0000 205b 0000 075d  .....BF .. [...]
0000010: 0000 0400 0000 0000 0000 2014 0000 0001  .......... .....
0000020: 0000 2014 0000 0001 0000 2031 0000 0001  .. ........ 1....
0000030: 0000 204e 0000 0000 0000 206b 0000 0000  .. N...... k....
0000040: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....
0000050: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....

0002000: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....
0002010: 0000 206b 0000 2018 0000 0000 0000 0001  .. k.. .........
0002020: 000f 736d 616c 6c5f 6469 722f 632e 7478  ..small_dir/c.tx
0002030: 7400 0020 3500 0000 0000 0000 0200 0f73  t.. 5..........s
0002040: 6d61 6c6c 5f64 6972 2f62 2e74 7874 0000  mall_dir/b.txt..
0002050: 2052 0000 0000 0000 0003 000f 736d 616c   R..........smal
0002060: 6c5f 6469 722f 612e 7478 7400 0000 8000  l_dir/a.txt.....
0002070: 0000 0000 0024 6f00 0000 0000 0024 6f00  .....$o......$o.
```

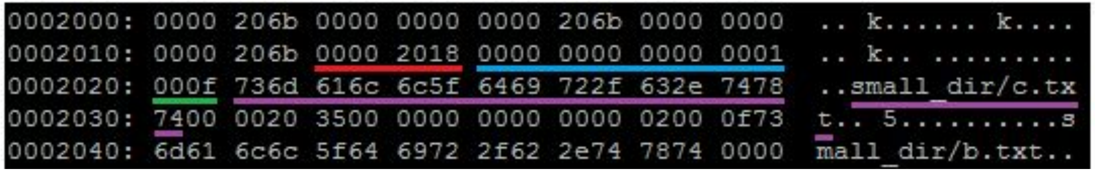


The header

Num buckets (Chain len Bucket offset)*

doctable



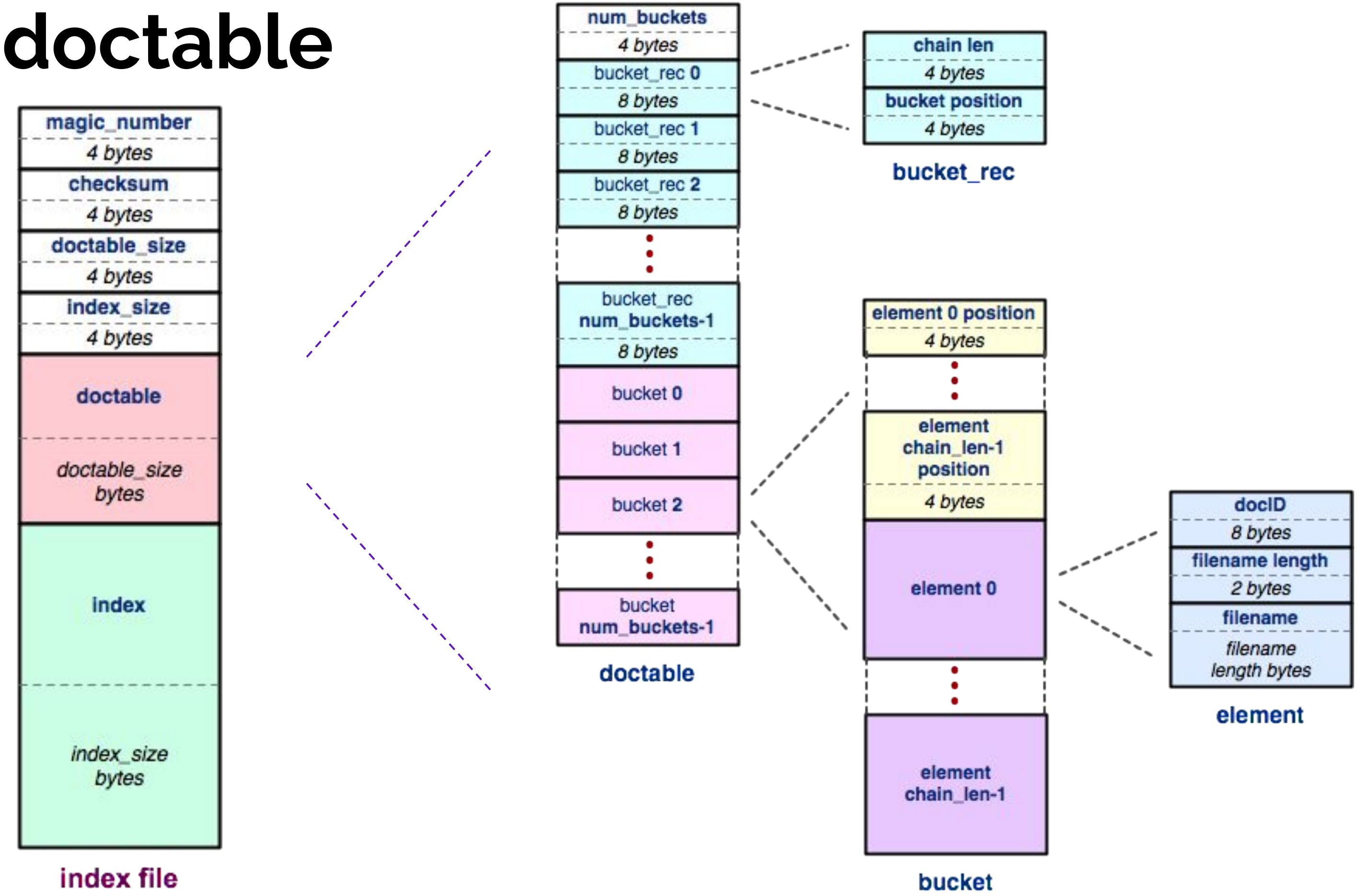


```
0002000: 0000 206b 0000 0000 0000 206b 0000 0000  .. k...... k....
0002010: 0000 206b 0000 2018 0000 0000 0000 0001  .. k.. .........
0002020: 000f 736d 616c 6c5f 6469 722f 632e 7478  ..small_dir/c.tx
0002030: 7400 0020 3500 0000 0000 0000 0200 0f73  t.. 5..........s
0002040: 6d61 6c6c 5f64 6972 2f62 2e74 7874 0000  mall_dir/b.txt..
```

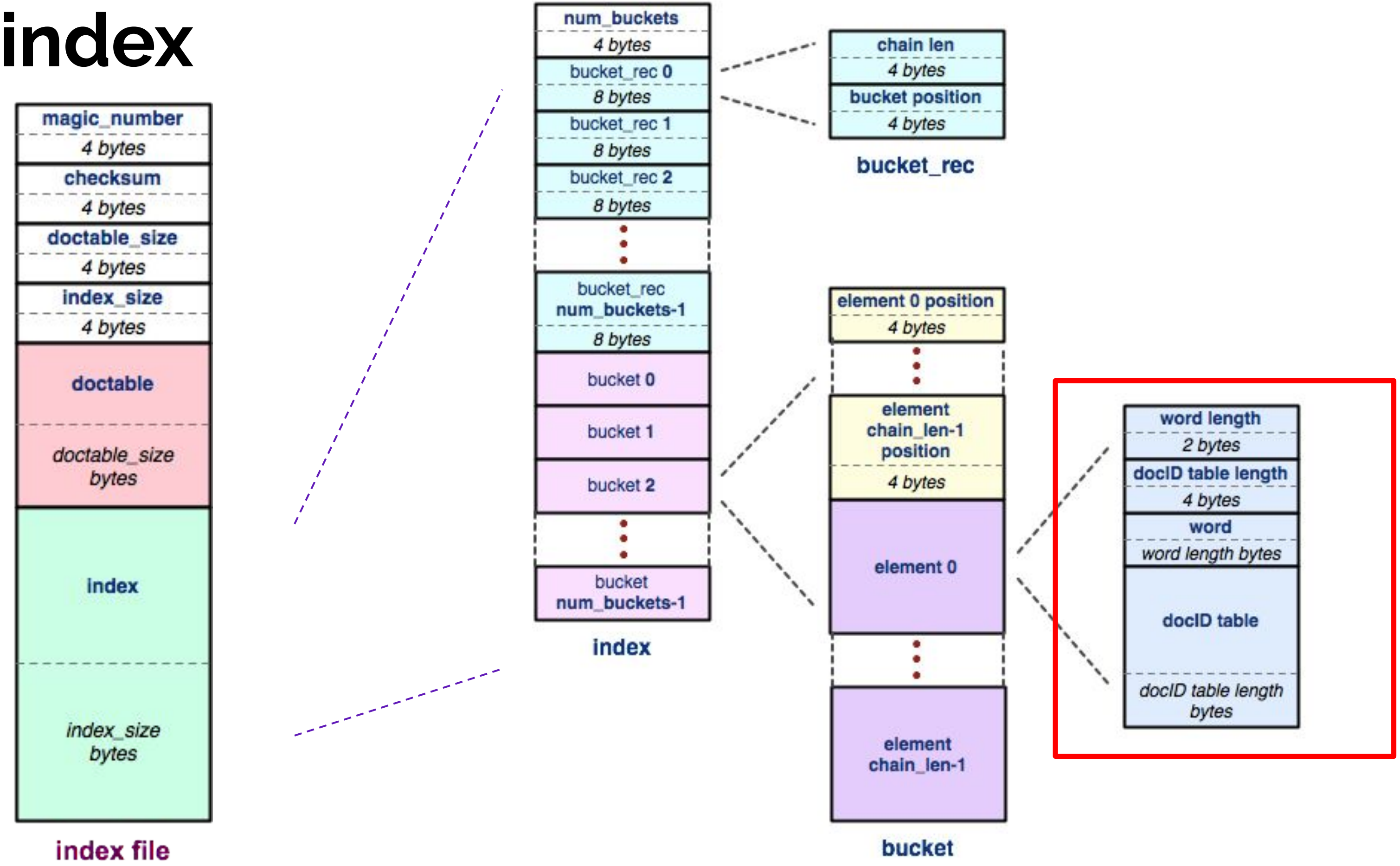
The buckets:

((Element offset)^n (DocID Filename len Filename)^n)*

doctable


magic_number
4 bytes
checksum
4 bytes
doctable_size
4 bytes
index_size
4 bytes
doctable
doctable_size bytes
index
index_size bytes
index file
num_buckets
4 bytes
bucket_rec 0
8 bytes
bucket_rec 1
8 bytes
bucket_rec 2
8 bytes
bucket_rec num_buckets-1
8 bytes
bucket 0
bucket 1
bucket 2
bucket num_buckets-1
doctable
chain len
4 bytes
bucket position
4 bytes
bucket_rec
element 0 position
4 bytes
element chain_len-1 position
4 bytes
element 0
element chain_len-1
bucket
docID
8 bytes
filename length
2 bytes
filename
filename length bytes
element

index



magic_number
4 bytes
checksum
4 bytes
doctable_size
4 bytes
index_size
4 bytes
doctable
doctable_size bytes
index
index_size bytes
index file

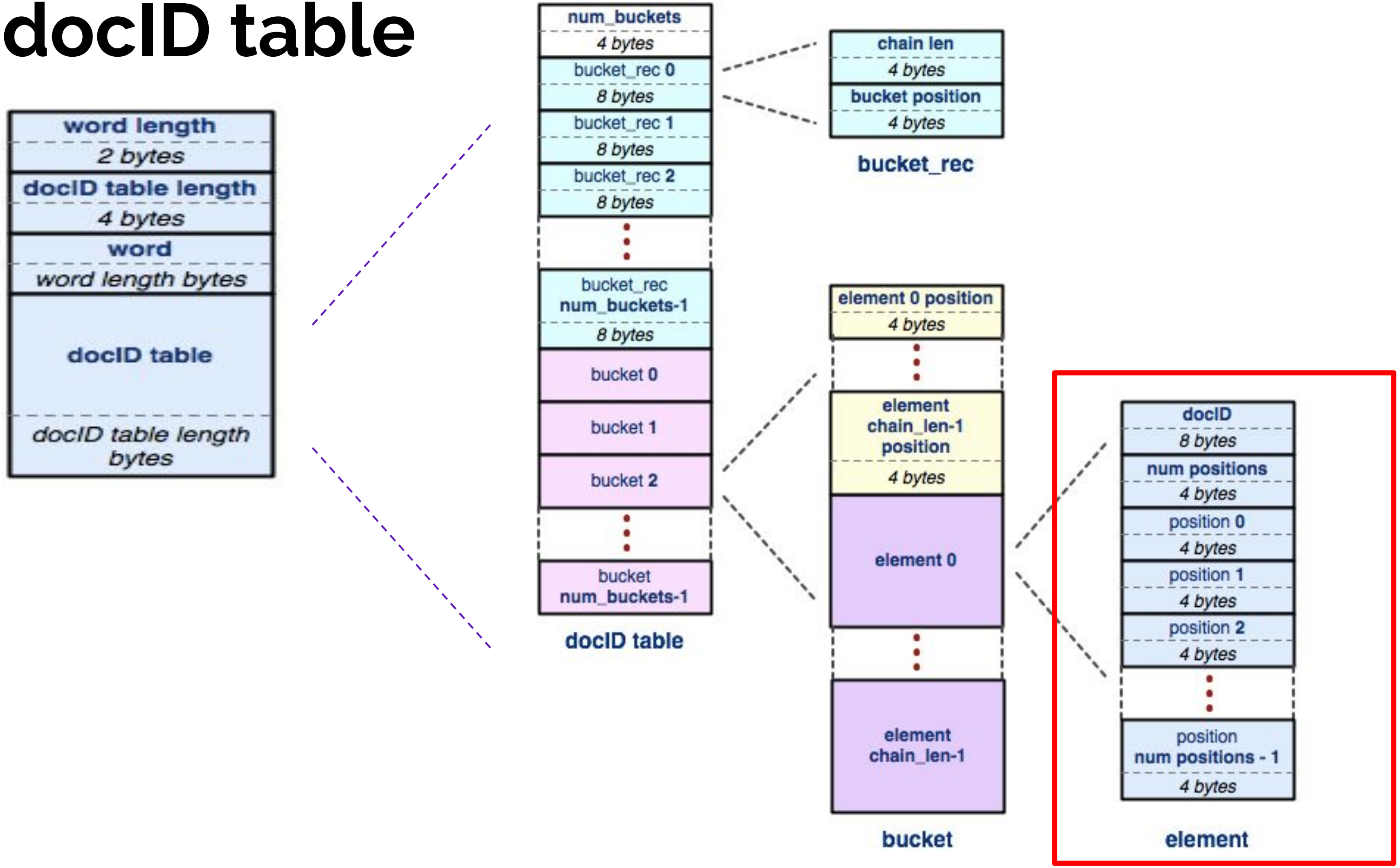
num_buckets
4 bytes
bucket_rec 0
8 bytes
bucket_rec 1
8 bytes
bucket_rec 2
8 bytes
bucket_rec num_buckets-1
8 bytes
bucket 0
bucket 1
bucket 2
bucket num_buckets-1
index

chain len
4 bytes
bucket position
4 bytes
bucket_rec

element 0 position
4 bytes
element chain_len-1 position
4 bytes
element 0
element chain_len-1
bucket

word length
2 bytes
docID table length
4 bytes
word
word length bytes
docID table
docID table length bytes

docID table



word length
2 bytes

docID table length
4 bytes

word
word length bytes

docID table
docID table length bytes

num_buckets
4 bytes

bucket_rec 0
8 bytes

bucket_rec 1
8 bytes

bucket_rec 2
8 bytes

bucket_rec num_buckets-1
8 bytes

bucket 0

bucket 1

bucket 2

bucket num_buckets-1

docID table

chain len
4 bytes

bucket position
4 bytes

bucket_rec

element 0 position
4 bytes

element chain_len-1 position
4 bytes

element 0

element chain_len-1

bucket

docID
8 bytes

num positions
4 bytes

position 0
4 bytes

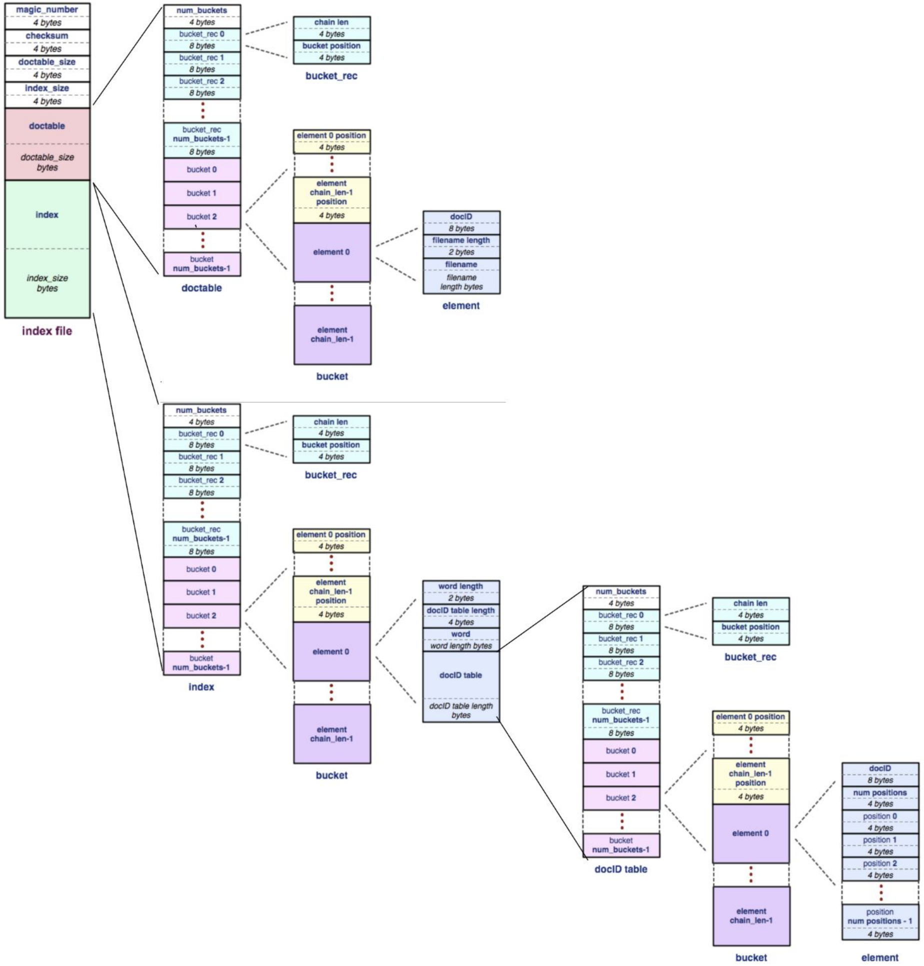
position 1
4 bytes

position 2
4 bytes

position num positions - 1
4 bytes

element

The Full Picture

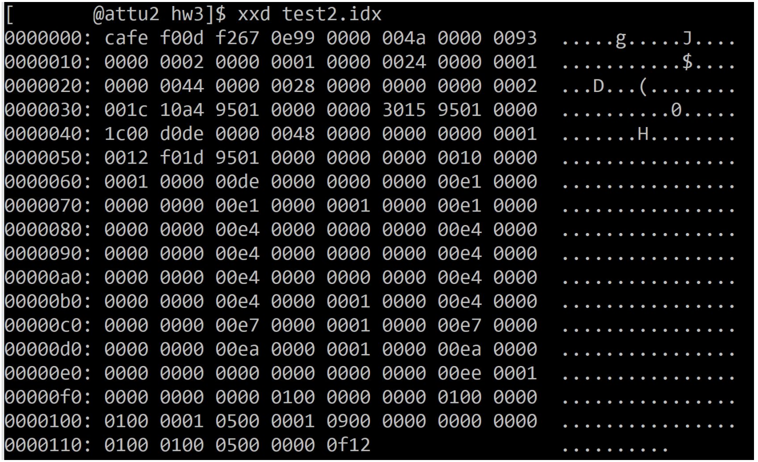


HW Tips

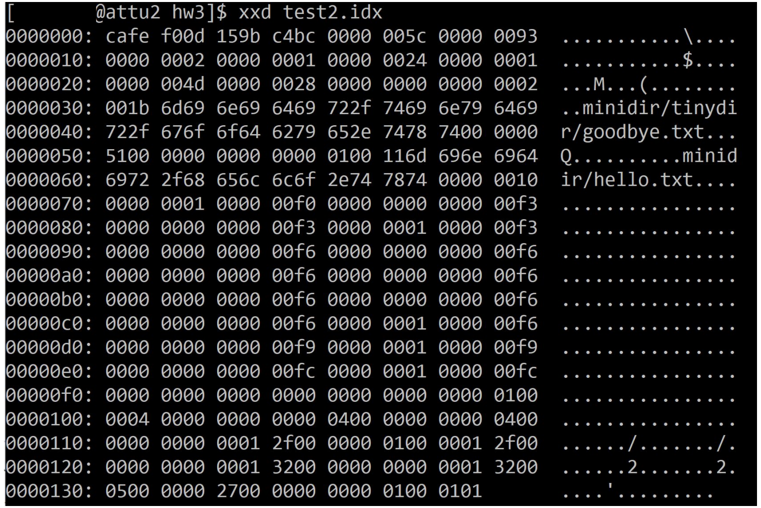
- When Writing, you should (almost) always:
  1. .toDiskFormat()
  2. fseek()
  3. fwrite()
- When Reading, you should (almost) always:
  1. fseek()
  2. fread()
  3. .toHostFormat()
- The most common bugs in the hw involve forgetting to change byte ordering, or forgetting to fseek().

Actual directory:

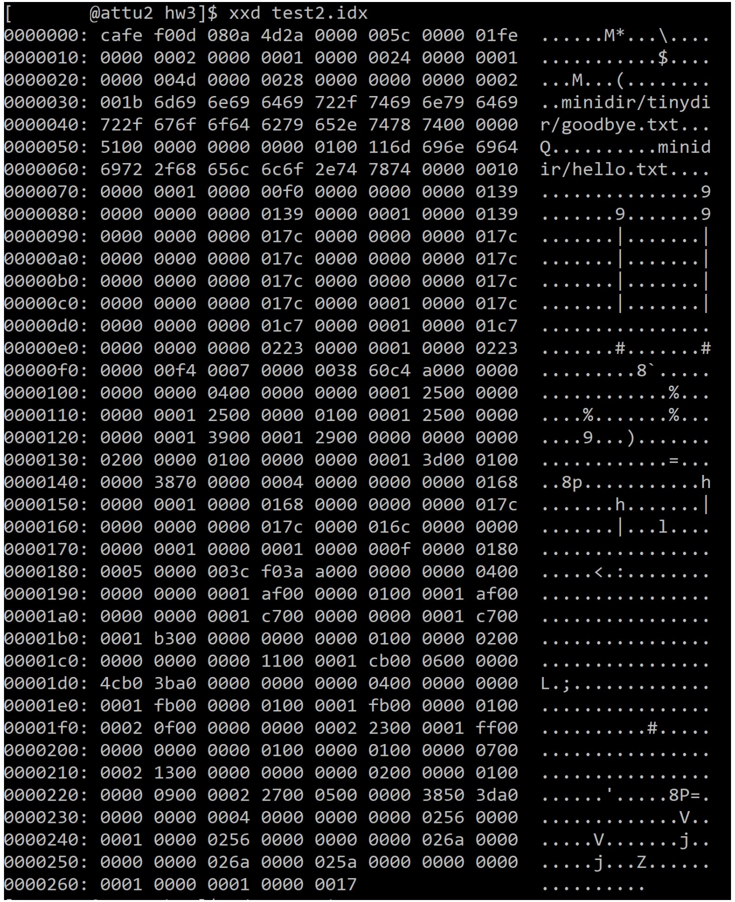
```
/minidir
   /tinydir
      goodbye.txt
   hello.txt
```



```
[[redacted]@attu2 hw3]$ xxd test2.idx
0000000: cafe f00d f267 0e99 0000 004a 0000 0093  .....g.....J....
0000010: 0000 0002 0000 0001 0000 0024 0000 0001  ...........$....
0000020: 0000 0044 0000 0028 0000 0000 0000 0002  ...D...(........
0000030: 001c 10a4 9501 0000 0000 3015 9501 0000  ..........0.....
0000040: 1c00 d0de 0000 0048 0000 0000 0000 0001  .......H........
0000050: 0012 f01d 9501 0000 0000 0000 0010 0000  ................
0000060: 0001 0000 00de 0000 0000 0000 00e1 0000  ................
0000070: 0000 0000 00e1 0000 0001 0000 00e1 0000  ................
0000080: 0000 0000 00e4 0000 0000 0000 00e4 0000  ................
0000090: 0000 0000 00e4 0000 0000 0000 00e4 0000  ................
00000a0: 0000 0000 00e4 0000 0000 0000 00e4 0000  ................
00000b0: 0000 0000 00e4 0000 0001 0000 00e4 0000  ................
00000c0: 0000 0000 00e7 0000 0001 0000 00e7 0000  ................
00000d0: 0000 0000 00ea 0000 0001 0000 00ea 0000  ................
00000e0: 0000 0000 0000 0000 0000 0000 00ee 0001  ................
00000f0: 0000 0000 0000 0100 0000 0000 0100 0000  ................
0000100: 0100 0001 0500 0001 0900 0000 0000 0000  ................
0000110: 0100 0100 0500 0000 0f12                 ..........
```



```
[[redacted]@attu2 hw3]$ xxd test2.idx
0000000: cafe f00d 159b c4bc 0000 005c 0000 0093  ...........\....
0000010: 0000 0002 0000 0001 0000 0024 0000 0001  ...........$....
0000020: 0000 004d 0000 0028 0000 0000 0000 0002  ...M...(........
0000030: 001b 6d69 6e69 6469 722f 7469 6e79 6469  ..minidir/tinydi
0000040: 722f 676f 6f64 6279 652e 7478 7400 0000  r/goodbye.txt...
0000050: 5100 0000 0000 0000 0100 116d 696e 6964  Q..........minid
0000060: 6972 2f68 656c 6c6f 2e74 7874 0000 0010  ir/hello.txt....
0000070: 0000 0001 0000 00f0 0000 0000 0000 00f3  ................
0000080: 0000 0000 0000 00f3 0000 0001 0000 00f3  ................
0000090: 0000 0000 0000 00f6 0000 0000 0000 00f6  ................
00000a0: 0000 0000 0000 00f6 0000 0000 0000 00f6  ................
00000b0: 0000 0000 0000 00f6 0000 0000 0000 00f6  ................
00000c0: 0000 0000 0000 00f6 0000 0001 0000 00f6  ................
00000d0: 0000 0000 0000 00f9 0000 0001 0000 00f9  ................
00000e0: 0000 0000 0000 00fc 0000 0001 0000 00fc  ................
00000f0: 0000 0000 0000 0000 0000 0000 0000 0100  ................
0000100: 0004 0000 0000 0000 0400 0000 0000 0400  ................
0000110: 0000 0000 0001 2f00 0000 0100 0001 2f00  ....../......./.
0000120: 0000 0000 0001 3200 0000 0000 0001 3200  ......2.......2.
0000130: 0500 0000 2700 0000 0000 0100 0101       ....'.........
```



```
[[redacted]@attu2 hw3]$ xxd test2.idx
0000000: cafe f00d 080a 4d2a 0000 005c 0000 01fe  ......M*...\....
0000010: 0000 0002 0000 0001 0000 0024 0000 0001  ...........$....
0000020: 0000 004d 0000 0028 0000 0000 0000 0002  ...M...(........
0000030: 001b 6d69 6e69 6469 722f 7469 6e79 6469  ..minidir/tinydi
0000040: 722f 676f 6f64 6279 652e 7478 7400 0000  r/goodbye.txt...
0000050: 5100 0000 0000 0000 0100 116d 696e 6964  Q..........minid
0000060: 6972 2f68 656c 6c6f 2e74 7874 0000 0010  ir/hello.txt....
0000070: 0000 0001 0000 00f0 0000 0000 0000 0139  ...............9
0000080: 0000 0000 0000 0139 0000 0001 0000 0139  .......9.......9
0000090: 0000 0000 0000 017c 0000 0000 0000 017c  .......|.......|
00000a0: 0000 0000 0000 017c 0000 0000 0000 017c  .......|.......|
00000b0: 0000 0000 0000 017c 0000 0000 0000 017c  .......|.......|
00000c0: 0000 0000 0000 017c 0000 0001 0000 017c  .......|.......|
00000d0: 0000 0000 0000 01c7 0000 0001 0000 01c7  ................
00000e0: 0000 0000 0000 0223 0000 0001 0000 0223  .......#.......#
00000f0: 0000 00f4 0007 0000 0038 60c4 a000 0000  .........8`.....
0000100: 0000 0000 0400 0000 0000 0001 2500 0000  ............%...
0000110: 0000 0001 2500 0000 0100 0001 2500 0000  ....%.......%...
0000120: 0000 0001 3900 0001 2900 0000 0000 0000  ....9...).......
0000130: 0200 0000 0100 0000 0000 0001 3d00 0100  ............=...
0000140: 0000 3870 0000 0004 0000 0000 0000 0168  ..8p...........h
0000150: 0000 0001 0000 0168 0000 0000 0000 017c  .......h.......|
0000160: 0000 0000 0000 017c 0000 016c 0000 0000  .......|...l....
0000170: 0000 0001 0000 0001 0000 000f 0000 0180  ................
0000180: 0005 0000 003c f03a a000 0000 0000 0400  .....<.:........
0000190: 0000 0000 0001 af00 0000 0100 0001 af00  ................
00001a0: 0000 0000 0001 c700 0000 0000 0001 c700  ................
00001b0: 0001 b300 0000 0000 0000 0100 0000 0200  ................
00001c0: 0000 0000 0000 1100 0001 cb00 0600 0000  ................
00001d0: 4cb0 3ba0 0000 0000 0000 0400 0000 0000  L.;.............
00001e0: 0001 fb00 0000 0100 0001 fb00 0000 0100  ................
00001f0: 0002 0f00 0000 0000 0002 2300 0001 ff00  ..........#.....
0000200: 0000 0000 0000 0100 0000 0100 0000 0700  ................
0000210: 0002 1300 0000 0000 0000 0200 0000 0100  ................
0000220: 0000 0900 0002 2700 0500 0000 3850 3da0  ......'.....8P=.
0000230: 0000 0000 0004 0000 0000 0000 0256 0000  .............V..
0000240: 0001 0000 0256 0000 0000 0000 026a 0000  .....V.......j..
0000250: 0000 0000 026a 0000 025a 0000 0000 0000  .....j...Z......
0000260: 0001 0000 0001 0000 0017                 ..........
```

Hex View Exercise

- Split up into break out rooms.
- Take a look at https://courses.cs.washington.edu/courses/cse333/21wi/sections/sec07.idx
  - Log into attu, use wget to download the file, then look into it.
- Try to figure out:

  How many documents are in this index?

  Which words are in each document?

Hex View Exercise

- Split up into break out rooms.
- Take a look at https://courses.cs.washington.edu/courses/cse333/20au/sections/sec06.idx
  - Log into attu, use wget to download the file, then look into it.
- Try to figure out:

  How many documents are in this index?

  Which words are in each document?

- **Answer: This index file was built off of test_tree/tiny**