HASHING

Runtimes of common Set operations

Data Structure	contains(element)	add(element)	remove(element)
Unsorted ArrayList			
Unsorted LinkedList			
Binary Search Tree			

Arrays

- Pros: O(1) time to set() or get() at a given index
- Cons: O(n) time to see if an element is in the array

What if we ***knew*** what index an object would be at?

Hash Function

- A function that maps any input deterministically to some output
  - If two objects are “equal”, their hash function **must** produce the same value
- We are concerned specifically with a hash function that maps **Object -> int**
- *All* Java Objects have a hashCode() method!

```
"Spongebob".hashCode() ==  907493499
"Patrick".hashCode()   ==  873506786
"Squidward".hashCode() == -759989618
```

Hash Table

- Array where we store elements at their hashed indexes

```
String[] hashTable = new String[10]
```

index	0	1	2	3	4	5	6	7	8	9
value	null	null	null	null	null	null	null	null	null	null

Where should these Strings go?

```
"Spongebob".hashCode() ==  907493499
"Patrick".hashCode()   ==  873506786
"Squidward".hashCode() == -759989618
```

```
int index = Math.abs(hashcode % hashTable.length)
```

Hash Table

```
public static int hashIndex(E element) {
    return Math.abs(element.hashCode() % hashTable.length);
}
```

```
contains(element):return hashTable[hashIndex(element)] != null
add(element)      :hashTable[hashIndex(element)] = element
remove(element)   :hashTable[hashIndex(element)] = null
```

What issues do we have?

Two elements might hash to the same spot!

This is called a **collision**

What Makes a Hash Function Good?

- To avoid collisions, different elements should hash to different values
  - We want the elements to be evenly spread out
  - We want the hash function to *appear* random

Rank these Hash Functions!

```
// Returns the length of the given string
public int hash(String s) {
   return s.length();
}
```

```
// Returns 0
public int hash(String s) {
   return 0;
}
```

```
// Returns the sum of the ascii values of
// the characters in the given string
public int hash(String s) {
   int hash = 0;
   for (int i = 0; i < s.length(); i++) {
      hash += (int) s.charAt(i);
   }
   return hash;
}
```

```
// Returns a random number between 0 and
// 100000
public int hash(String s) {
   Random r = new Random();
   return r.nextInt(100000);
}
```

What Makes a Hash Function Good? Java's String hashCode()

```
public int hashCode() {
    int h = hash;
    if (h == 0 && value.length > 0) {
        char val[] = value;

        for (int i = 0; i < value.length; i++) {
            h = 31 * h + val[i];
        }
        hash = h;
    }
    return h;
}
```

What issues do we have?

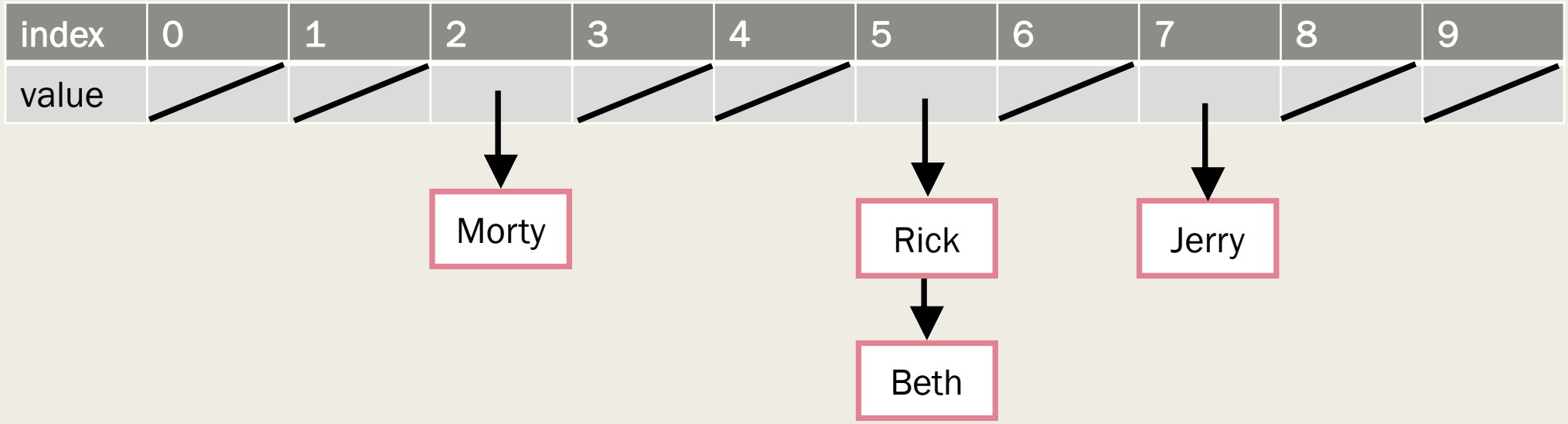
Two elements might hash to the same spot!

This is called a **collision**

We can only have 10 elements!

Separate Chaining

- Solve collisions *and* running out of space by storing a list at each index!
  - contains/add/remove must now traverse lists



Is this really O(1) though?

How long do you expect the average chain to be if there are 30 elements in a hash table of size 10?

Load Factor : (# of elements in hash table) / (length of hash table)

As long as we limit the length of each chain **to a constant number**, it will be O(1)!

Rehashing

- **Load Factor :** (# of elements in hash table) / (length of hash table)
  - The length of the average chain
- **Rehashing :** Once the load factor becomes too high, we hash everything again into a bigger array
  - Usually rehash when load factor is around 0.75
  - Why can't we copy into the new array?

This is **Amortized** O(1)