Concurrency in Go

9/21/18

Outline

Mapreduce (15 mins)

Two synchronization mechanisms

- Locks (15 mins)
- Channels (20 mins)

Application: Word count

How much wood would a woodchuck chuck
if a woodchuck could chuck wood?

```
how: 1, much: 1, wood: 2, would: 1, a: 2, woodchuck: 2,
chuck: 2, if: 1, could: 1
```

Application: Word count

Locally: tokenize and put words in a hash map

How do you parallelize this?

Split document by half

Build two hash maps, one for each half

Merge the two hash maps (by key)

How do you do this in a distributed environment?

When in the Course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume, among the Powers of the earth, the separate and equal station to which the Laws of Nature and of Nature's God entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.

Input document

When in the Course of human events, it becomes necessary for one people to

dissolve the political bands which have connected them with another, and to assume,

among the Powers of the earth, the separate and equal station to which the Laws of

Nature and of Nature's God entitle them, a decent respect to the opinions of mankind

requires that they should declare the causes which impel them to the separation.

Partition

requires that they
should declare the
causes which impel them
to the separation.

When in the Course of
human events, it
becomes necessary for
one people to

Nature and of Nature's
God entitle them, a
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bands which have
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equal station to which
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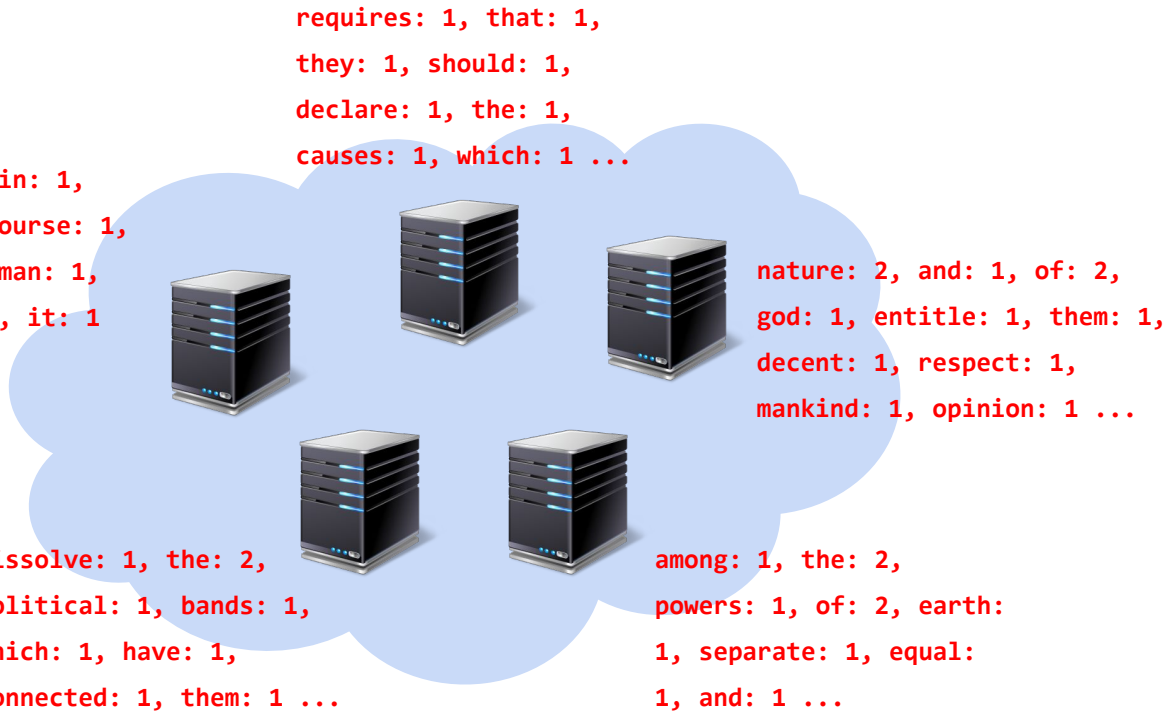


Compute word counts locally

requires: 1, that: 1,
they: 1, should: 1,
declare: 1, the: 1,
causes: 1, which: 1 ...

when: 1, in: 1,
the: 1, course: 1,
of: 1, human: 1,
events: 1, it: 1

Now what…
How to merge results?

nature: 2, and: 1, of: 2,
god: 1, entitle: 1, them: 1,
decent: 1, respect: 1,
mankind: 1, opinion: 1 ...

dissolve: 1, the: 2,
political: 1, bands: 1,
which: 1, have: 1,
connected: 1, them: 1 ...

among: 1, the: 2,
powers: 1, of: 2, earth:
1, separate: 1, equal:
1, and: 1 ...

Compute word counts locally

Merging results computed locally

Several options

Don’t merge — requires additional computation for correct results

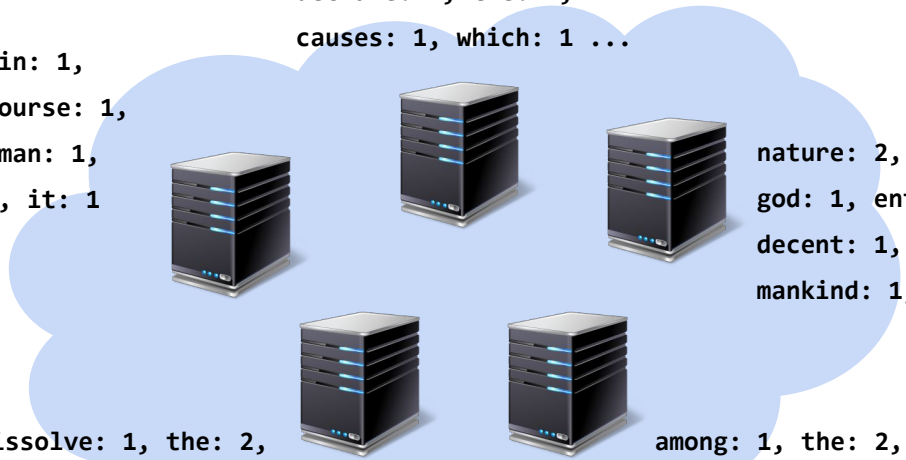
Send everything to one node — what if data is too big? Too slow…

Partition key space among nodes in cluster (e.g. `[a-e]`, `[f-j]`, `[k-p]` …)

1. Assign a key space to each node
2. Split local results by the key spaces
3. Fetch and merge results that correspond to the node’s key space

requires: 1, that: 1,
they: 1, should: 1,
declare: 1, the: 1,
causes: 1, which: 1 ...

when: 1, in: 1,
the: 1, course: 1,
of: 1, human: 1,
events: 1, it: 1



nature: 2, and: 1, of: 2,
god: 1, entitle: 1, them: 1,
decent: 1, respect: 1,
mankind: 1, opinion: 1 ...

dissolve: 1, the: 2,
political: 1, bands: 1,
which: 1, have: 1,
connected: 1, them: 1 ...

among: 1, the: 2,
powers: 1, of: 2, earth:
1, separate: 1, equal:
1, and: 1 ...

[a-e]

[f-j]

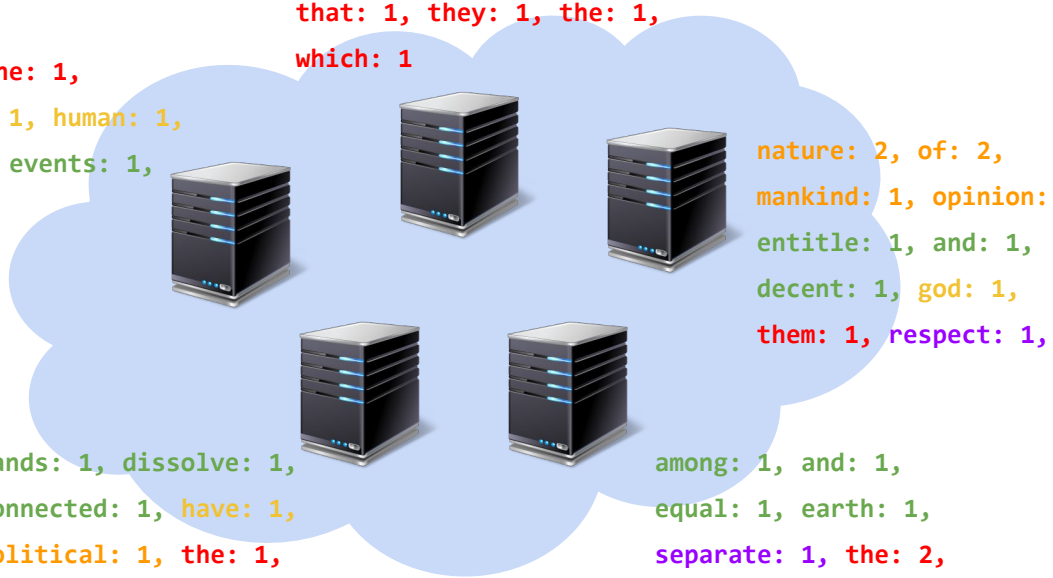
[k-p]

[q-s]

[t-z]

causes: 1, declare: 1,
requires: 1, should: 1,
that: 1, they: 1, the: 1,
which: 1

when: 1, the: 1,
in: 1, it: 1, human: 1,
course: 1, events: 1,
of: 1

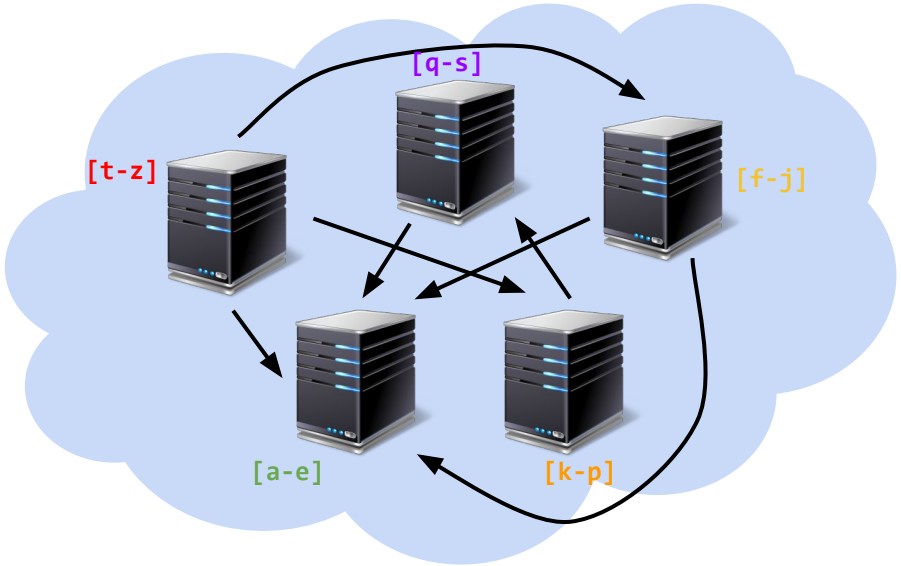


nature: 2, of: 2,
mankind: 1, opinion: 1,
entitle: 1, and: 1,
decent: 1, god: 1,
them: 1, respect: 1,

bands: 1, dissolve: 1,
connected: 1, have: 1,
political: 1, the: 1,
them: 1, which: 1

among: 1, and: 1,
equal: 1, earth: 1,
separate: 1, the: 2,
powers: 1, of: 2

Split local results by key space



All-to-all shuffle

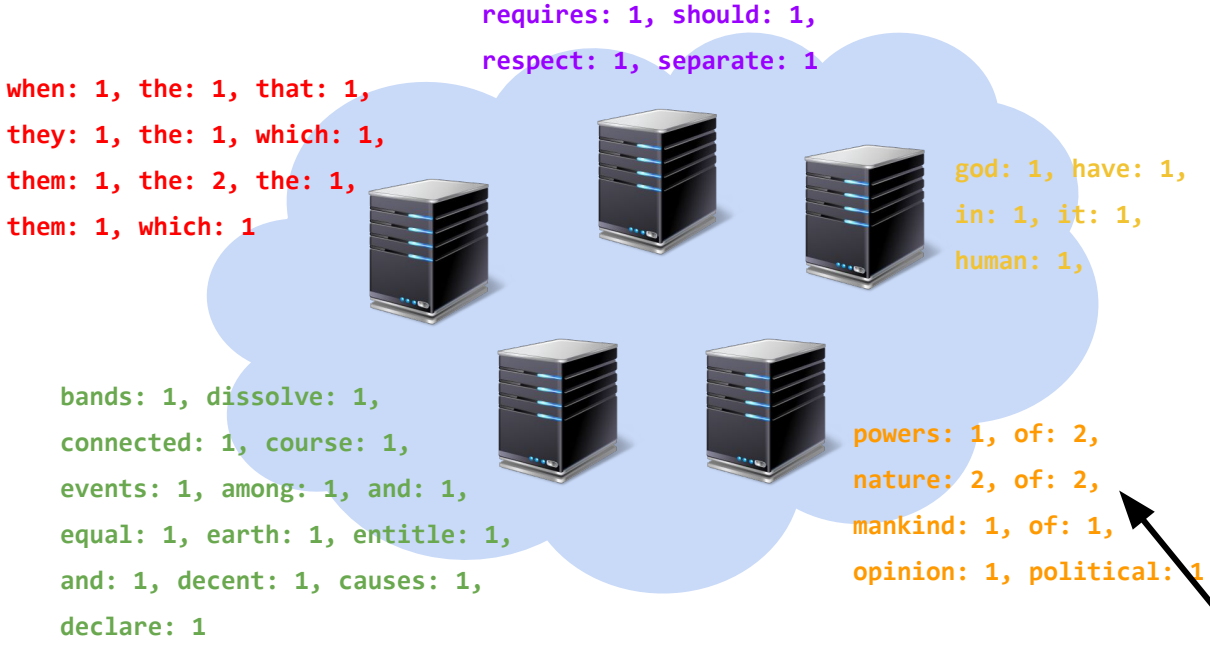
[a-e]

[f-j]

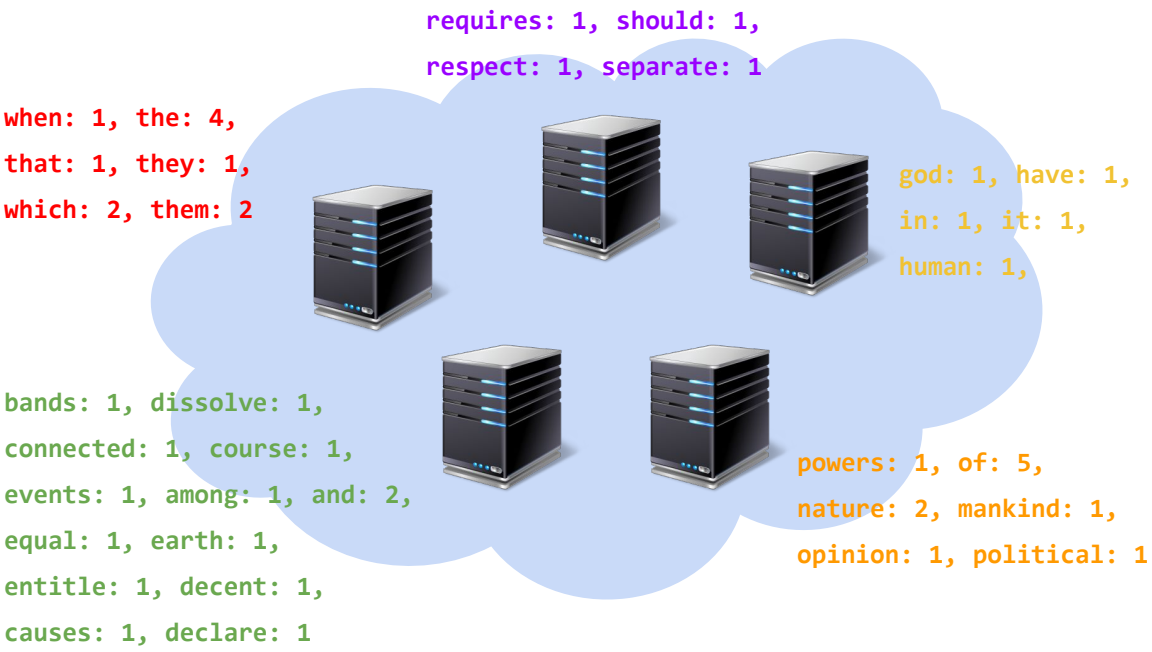
[k-p]

[q-s]

[t-z]



Note the duplicates...



Merge results received from other nodes

Mapreduce

Partition dataset into many chunks

Map stage: Each node processes one or more chunks locally

Reduce stage: Each node fetches and merges partial results from all other nodes

Mapreduce Interface

`map(key, value) -> list(<k', v'>)`

Apply function to (key, value) pair

Outputs list of intermediate pairs

`reduce(key, list<value>) -> <k', v'>`

Applies aggregation function to values

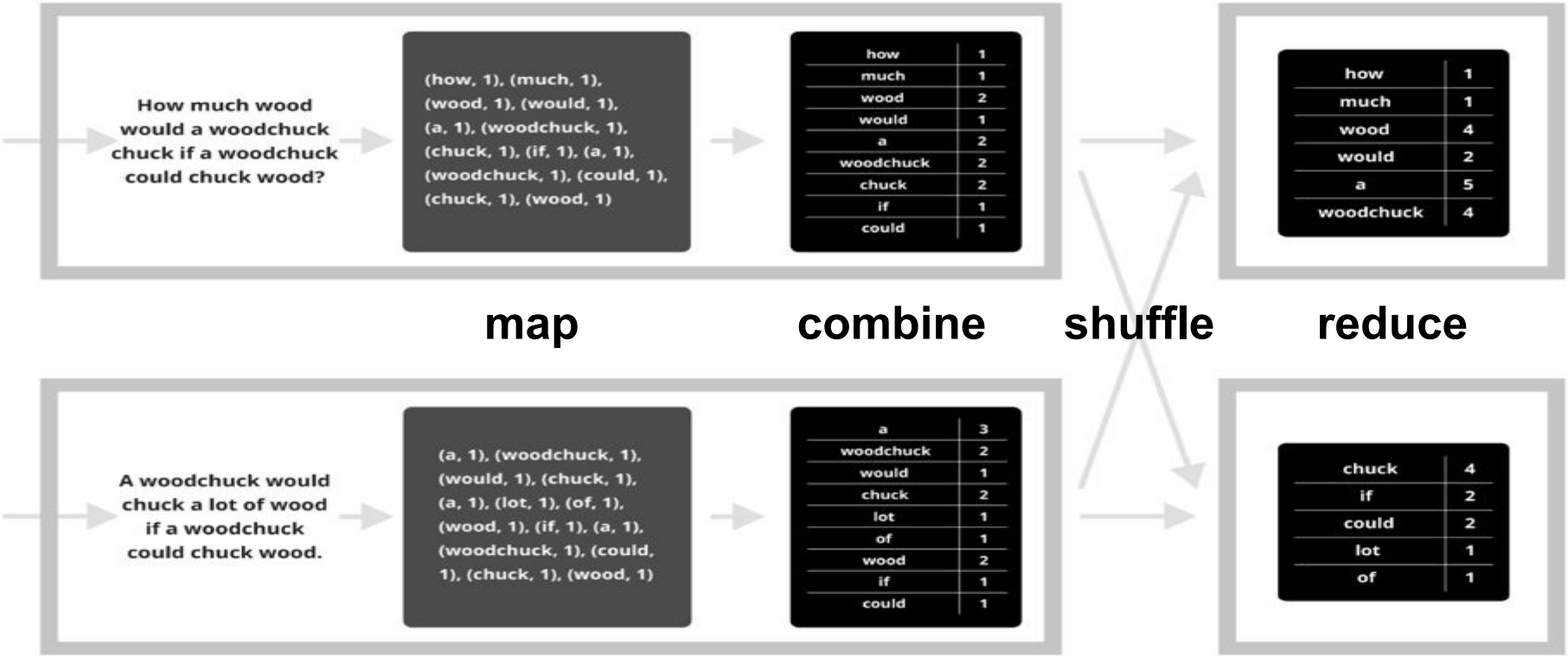
Outputs result

Mapreduce: Word count

```
map(key, value):
    // key = document name
    // value = document contents
    for each word w in value:
        emit (w, 1)

reduce(key, values):
    // key = the word
    // values = number of occurrences of that word
    count = sum(values)
    emit (key, count)
```

Mapreduce: Word count



Why is this hard?

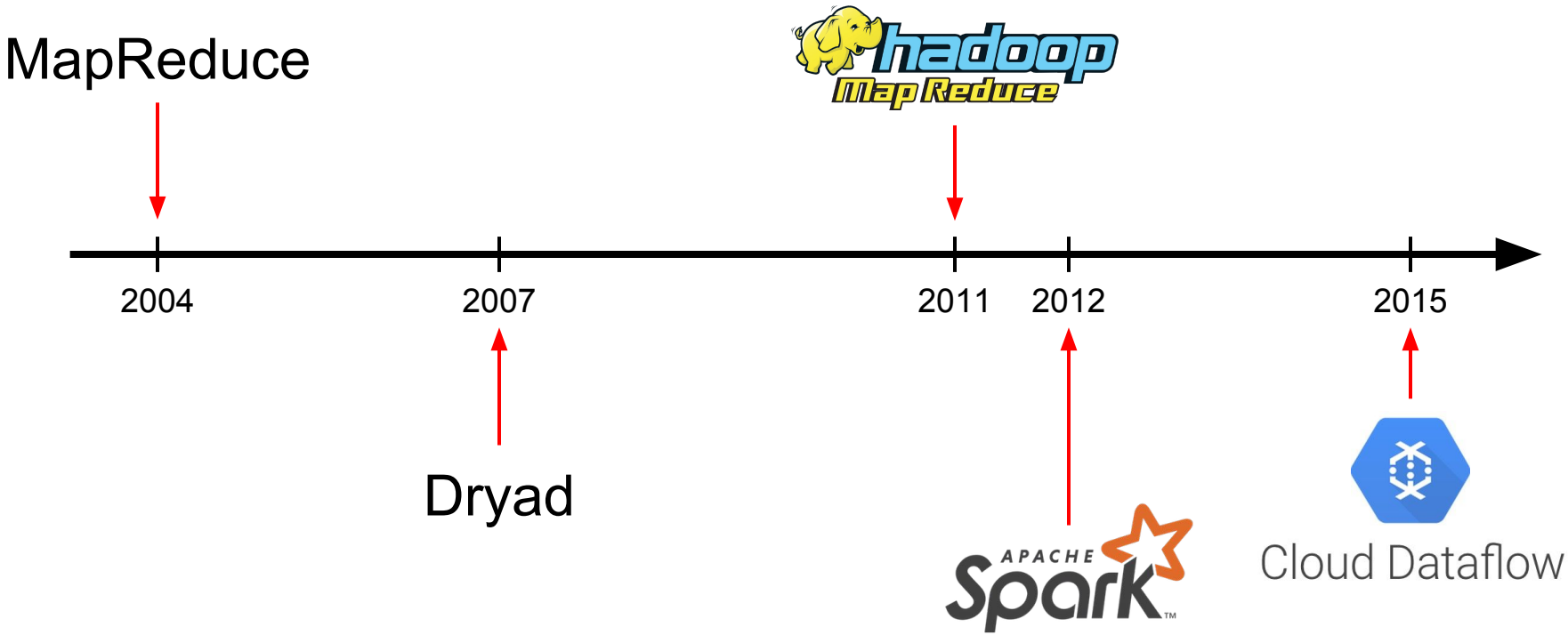
Failure is common

> Even if each machine is available p = 99.999% of the time, a datacenter with n = 100,000 machines still encounters failures $(1-p^n) = 63\%$ of the time

Data skew causes unbalanced performance across cluster

Problems occur at scale

Hard to debug!

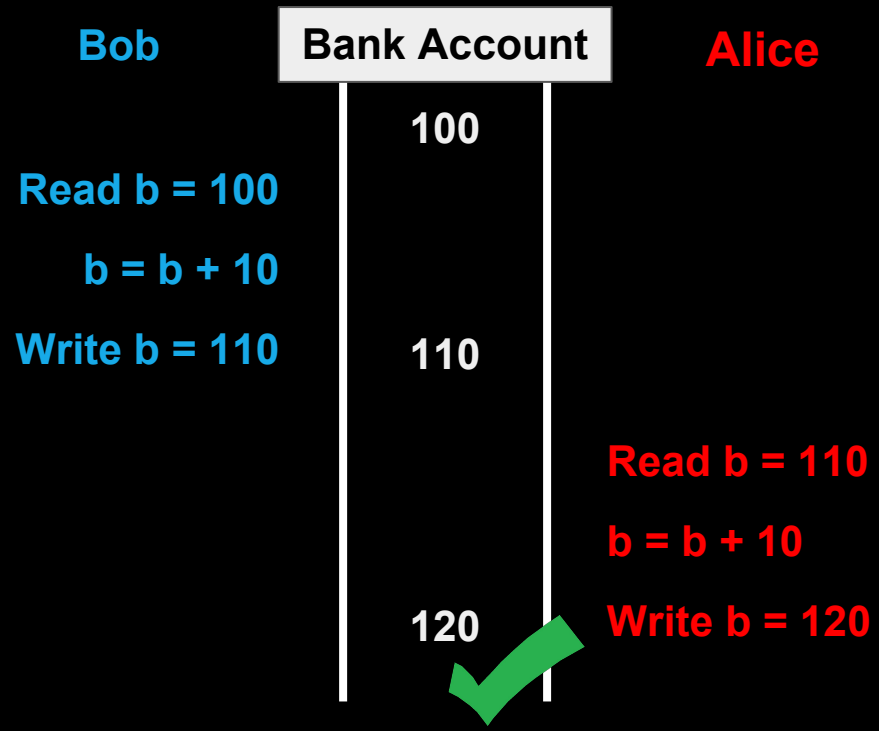

MapReduce
hadoop
Map Reduce
2004
2007
2011
2012
2015
Dryad
APACHE
Spark
Cloud Dataflow

Two synchronization mechanisms

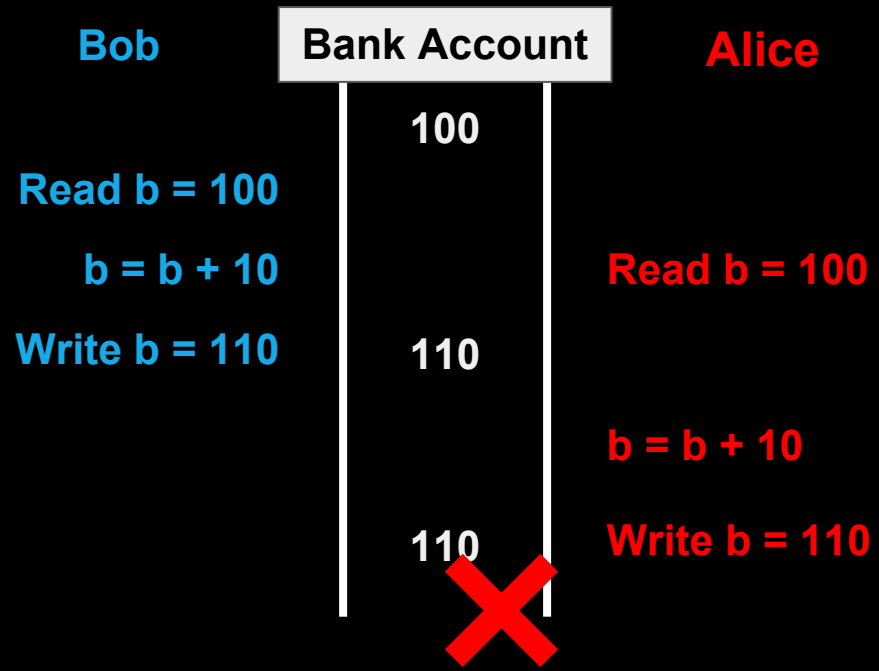
Locks - limit access to a critical section

Channels - pass information across processes using a queue

Example: Bank account



Example: Bank account



What went wrong?

Changes to balance are not ***atomic***

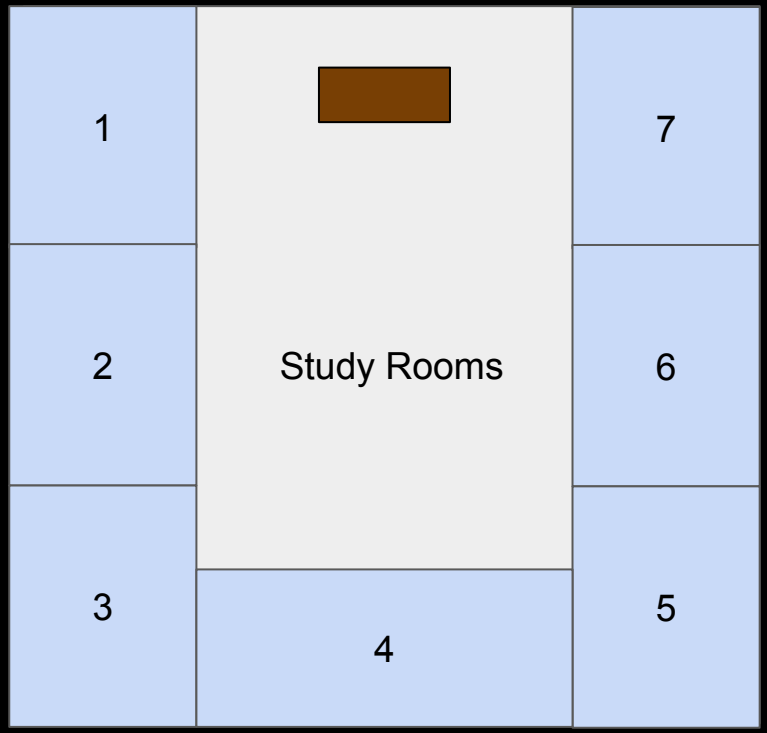
```
func Deposit(amount) {
    lock balance
    read balance
    balance += amount
    write balance
    unlock balance
}
```

Critical section

Semaphores

Allows at most *n* concurrent accesses

Locks are a special case of semaphores, with *n* = 1



Locks in Go

```
package account

import "sync"

type Account struct {
    balance int
    lock sync.Mutex
}

func NewAccount(init int) Account {
    return Account{balance: init}
}
```

```
func (a *Account) CheckBalance() int {
    a.lock.Lock()
    defer a.lock.Unlock()
    return a.balance
}

func (a *Account) Withdraw(v int) {
    a.lock.Lock()
    defer a.lock.Unlock()
    a.balance -= v
}

func (a *Account) Deposit(v int) {
    a.lock.Lock()
    defer a.lock.Unlock()
    a.balance += v
}
```

Read Write Locks in Go

```go
package account

import "sync"

type Account struct {
    balance int
    lock sync.RWMutex
}


func NewAccount(init int) Account {
    return Account{balance: init}
}
```

```go
func (a *Account) CheckBalance() int {
    a.lock.RLock()
    defer a.lock.RUnlock()
    return a.balance
}


func (a *Account) Withdraw(v int) {
    a.lock.Lock()
    defer a.lock.Unlock()
    a.balance -= v
}


func (a *Account) Deposit(v int) {
    a.lock.Lock()
    defer a.lock.Unlock()
    a.balance += v
}
```

Go channels

In Go, ***channels*** and ***goroutines*** are more idiomatic than locks

```
result := make(chan int, numWorkers)

// Launch workers
for i := 0; i < numWorkers; i++ {
    go func() {
        // ... do some work
        result <- i
    }()
}

// Wait until all worker threads have finished
for i := 0; i < numWorkers; i++ {
    handleResult(<-result)
}
fmt.Println("Done!")
```

Go channels

Easy to express asynchronous RPC

Awkward to express this using locks

```
result := make(chan int, numServers)

// Send query to all servers
for i := 0; i < numServers; i++ {
    go func() {
        resp := // ... send RPC to server
        result <- resp
    }()
}

// Return as soon as the first server responds
handleResponse(<-result)
```

Bank Account Code (using channels)

```
package account

type Account struct {
    // Fill in Here
}

func NewAccount(init int) Account {
    // Fill in Here
}
```

```
func (a *Account) CheckBalance() int {
    // What goes Here?
}

func (a *Account) Withdraw(v int) {
    // ???
}

func (a *Account) Deposit(v int) {
    // ???
}
```

Bank Account Code (using channels)

```go
package account

type Account struct {
	balance chan int
}

func NewAccount(init int) Account {
	a := Account{make(chan int, 1)}
	a.balance <- init
	return a
}
```

```go
func (a *Account) CheckBalance() int {
	// What goes Here?
}

func (a *Account) Withdraw(v int) {
	// ???
}

func (a *Account) Deposit(v int) {
	// ???
}
```

Bank Account Code (using channels)

```
package account

type Account struct {
     balance chan int
}

func NewAccount(init int) Account {
     a := Account{make(chan int, 1)}
     a.balance <- init
     return a
}
```

```
func (a *Account) CheckBalance() int {
     bal := <-a.balance
     a.balance <- bal
     return bal
}

func (a *Account) Withdraw(v int) {
     // ???
}

func (a *Account) Deposit(v int) {
     //???
}
```

Bank Account Code (using channels)

```
package account

type Account struct {
     balance chan int
}

func NewAccount(init int) Account {
     a := Account{make(chan int, 1)}
     a.balance <- init
     return a
}
```

```
func (a *Account) CheckBalance() int {
     bal := <-a.balance
     a.balance <- bal
     return bal
}

func (a *Account) Withdraw(v int) {
     bal := <-a.balance
     a.balance <- (bal - v)
}

func (a *Account) Deposit(v int) {
     //???
}
```

Bank Account Code (using channels)

```
package account

type Account struct {
     balance chan int
}

func NewAccount(init int) Account {
     a := Account{make(chan int, 1)}
     a.balance <- init
     return a
}
```

```
func (a *Account) CheckBalance() int {
     bal := <-a.balance
     a.balance <- bal
     return bal
}

func (a *Account) Withdraw(v int) {
     bal := <-a.balance
     a.balance <- (bal - v)
}

func (a *Account) Deposit(v int) {
     bal := <-a.balance
     a.balance <- (bal + v)
}
```

Select statement

`select` allows a goroutine to wait on multiple channels at once

```
for {
     select {
          case money := <-dad:
               buySnacks(money)
          case money := <-mom:
               buySnacks(money)
     }
}
```

Select statement

`select` allows a goroutine to wait on multiple channels at once

```
for {
     select {
          case money := <-dad:
               buySnacks(money)
          case money := <-mom:
               buySnacks(money)
          case default:
               starve()
               time.Sleep(5 * time.Second)
     }
}
```

Handle timeouts using `select`

```
result := make(chan int)
timeout := make(chan bool)

// Asynchronously request an
// answer from server, timing
// out after X seconds
askServer(result, timeout)

// Wait on both channels
select {
     case res := <-result:
          handleResult(res)
     case <-timeout:
          fmt.Println("Timeout!")
}
```

```
func askServer(
     result chan int,
     timeout chan bool) {

     // Start timer
     go func() {
          time.Sleep(5 * time.Second)
          timeout <- true
     }()

     // Ask server
     go func() {
          response := // ... send RPC
          result <- response
     }()
}
```

Handle timeouts using `select`

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result := make(chan int)
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// Asynchronously request an
// answer from server, timing
// out after X seconds
askServer(result, timeout)

// Wait on both channels
select {
     case res := <-result:
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}
```

```
func askServer(
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     // Start timer
     go func() {
          time.Sleep(5 * time.Second)
          timeout <- true
     }()

     // Ask server
     go func() {
          response := // ... send RPC
          result <- response
     }()
}
```

Exercise: Locks and semaphores (using channels)

```
type Lock struct {
    // ???
}

func NewLock() Lock {
    // ???
}

func (l *Lock) Lock() {
    // ???
}

func (l *Lock) Unlock() {
    // ???
}
```

```
type Semaphore struct {
    // ???
}

func NewSemaphore(n int) Semaphore {
    // ???
}

func (s *Semaphore) Acquire() {
    // ???
}

func (s *Semaphore) Release() {
    // ???
}
```

Exercise: Locks and semaphores (using channels)

```
type Lock struct {
    ch chan bool
}

func NewLock() Lock {
    l := Lock{make(chan bool, 1)}
    l.ch <- true
    return l
}

func (l *Lock) Lock() {
    <-l.ch
}

func (l *Lock) Unlock() {
    l.ch <- true
}
```

```
type Semaphore struct {
    ch chan bool
}

func NewSemaphore(n int) Semaphore {
    s := Semaphore{make(chan bool, n)}
    for i := 0; i < n; i++ {
        s.ch <- true
    } return s
}

func (s *Semaphore) Acquire() {
    <-s.ch
}

func (s *Semaphore) Release() {
    s.ch <- true
}
```

Assignment 1.2 is out, due 9/27