# Principles of Software Construction

## Introduction to distributed systems

Josh Bloch **Charlie Garrod**

School of Computer Science
institute for SOFTWARE RESEARCH

# Administrivia

- Homework 5 Best Frameworks available tonight

# Key concepts from Tuesday

# Concurrency at the language level

- Consider:

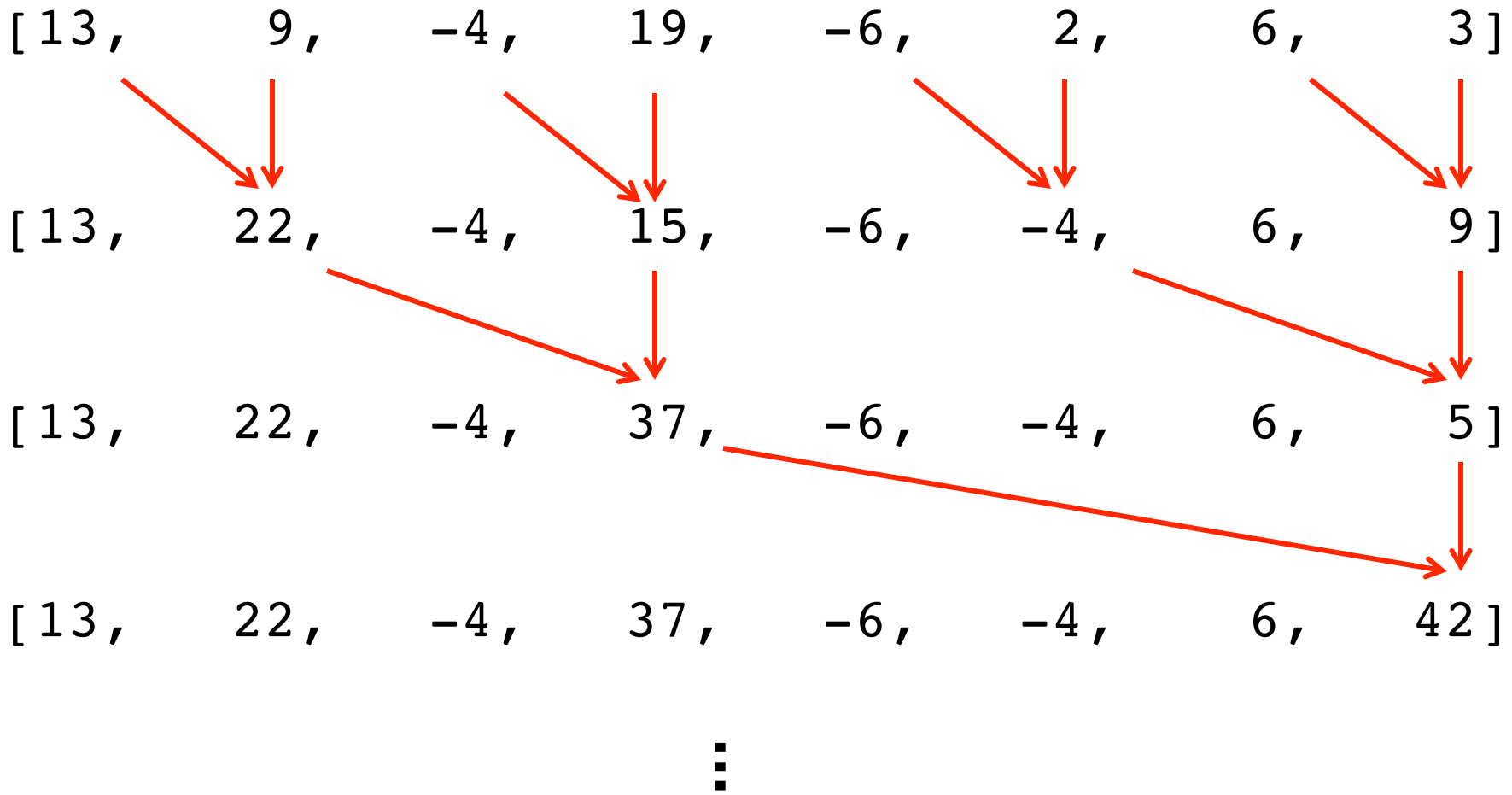
```
Collection<Integer> collection = …;
int sum = 0;
for (int i : collection) {
    sum += i;
}
```

- In python:

```
collection = …
sum = 0
for item in collection:
    sum += item
```

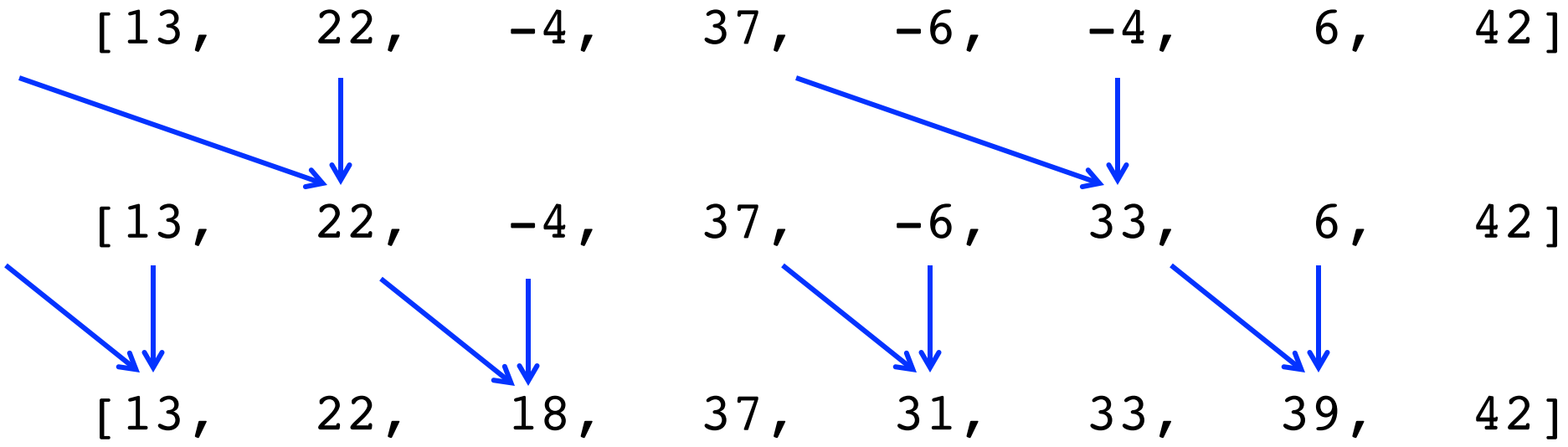
# Parallel prefix sums algorithm, upsweep

- Computes the partial sums in a more useful manner



# Parallel prefix sums algorithm, downsweep

- Now unwinds to calculate the other sums




- Recall, we started with:

[13, 9, -4, 19, -6, 2, 6, 3]

# A framework for asynchronous computation

- The `java.util.concurrent.Future<V>` interface:

```
V           get();
V           get(long timeout, TimeUnit unit);
boolean     isDone();
boolean     cancel(boolean mayInterruptIfRunning);
boolean     isCancelled();
```

- The `java.util.concurrent.ExecutorService` interface:

```
Future<?>  submit(Runnable task);
Future<V>  submit(Callable<V> task);
List<Future<V>>
      invokeAll(Collection<? extends Callable<V>> tasks);
Future<V>
      invokeAny(Collection<? extends Callable<V>> tasks);
void shutdown();
```

# Fork/Join: another common computational pattern

- In a long computation:
  - Fork a thread (or more) to do some work
  - Join the thread(s) to obtain the result of the work
- The `java.util.concurrent.ForkJoinPool` class
  - Implements `ExecutorService`
  - Executes `java.util.concurrent.ForkJoinTask<V>` or `java.util.concurrent.RecursiveTask<V>` or `java.util.concurrent.RecursiveAction`

# Parallel prefix sums algorithm

- How good is this?
  - Work: O(n)
  - Depth: O(lg n)
- See `PrefixSumsParallelArrays.java`
- See `PrefixSumsSequential.java`
  - n-1 additions
  - Memory access is sequential
- For `PrefixSumsSequentialWithParallelWork.java`
  - About 2n useful additions, plus extra additions for the loop indexes
  - Memory access is non-sequential
- The punchline:
  - Don't roll your own
  - Cache and constants matter

# Today: Distributed system design

- Java networking fundamentals
- Introduction to distributed systems
  - Challenges
  - Motivation: reliability and scalability
  - Failure models

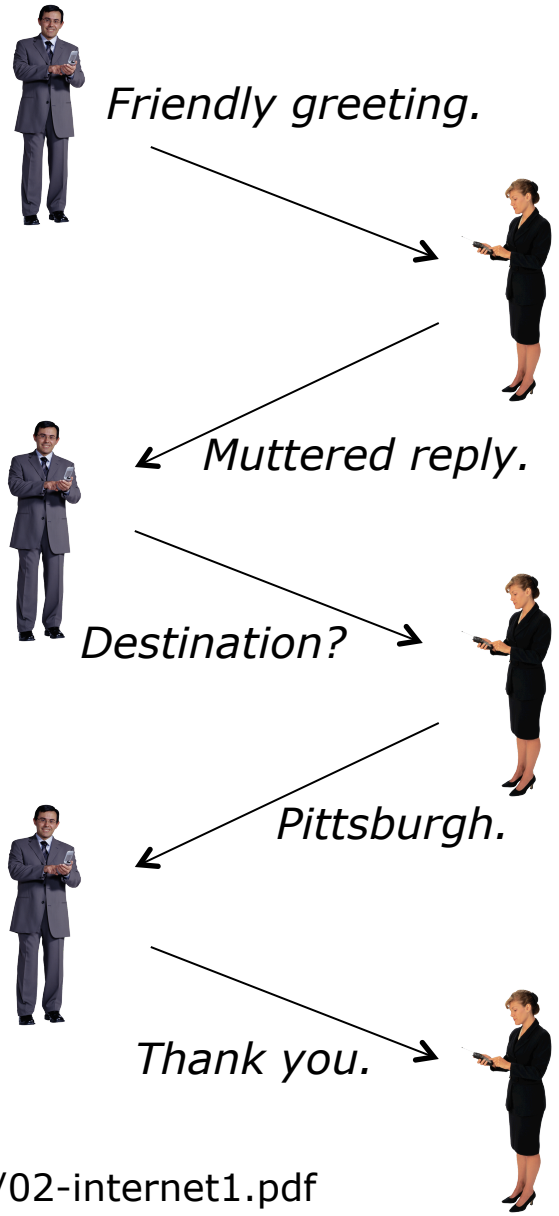
# Our destination: Distributed systems

- Multiple system components (computers) communicating via some medium (the network)
- Challenges:
  - Scale
  - Concurrency
  - Heterogeneity
  - Geography
  - Failures
  - Security

(courtesy of http://www.cs.cmu.edu/~dga/15-440/F12/lectures/02-internet1.pdf

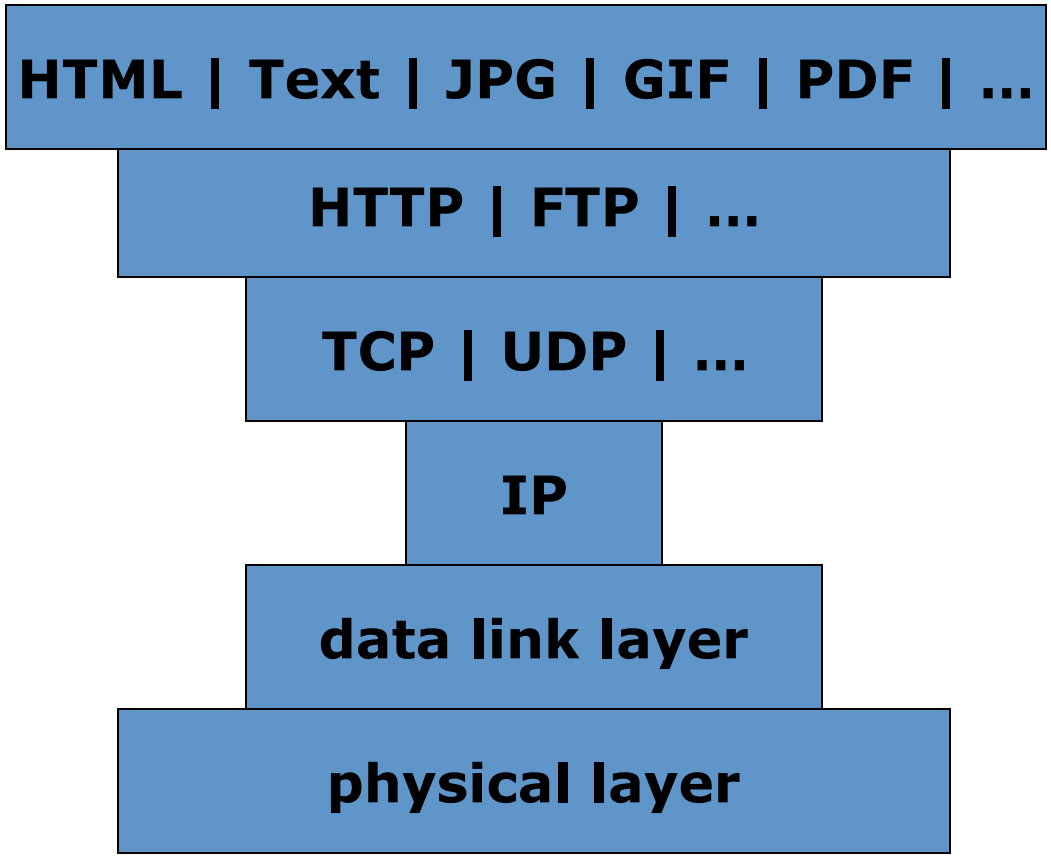
# Abstraction: Communication protocols

- Agreement between parties for how communication should take place




(courtesy of http://www.cs.cmu.edu/~dga/15-440/F12/lectures/02-internet1.pdf

# Abstractions of a network connection



# Internet addresses and sockets

- For IP version 4 (IPv4) host address is a 4-byte number
  - e.g. 127.0.0.1
  - Hostnames mapped to host IP addresses via DNS
  - ~4 billion distinct addresses
- Port is a 16-bit number (0-65535), assigned conventionallly
  - e.g., port 80 is the standard port for web servers

# Packet-oriented and stream-oriented connections

- UDP: User Datagram Protocol
  - Unreliable, discrete packets of data
- TCP: Transmission Control Protocol
  - Reliable data stream

# TCP, networking in Java

- The java.net.InetAddress:

```
static InetAddress getByName(String host);
static InetAddress getByAddress(byte[] b);
static InetAddress getLocalHost();
```

- The java.net.Socket:

```
Socket(InetAddress addr, int port);
boolean      isConnected();
boolean      isClosed();
void         close();
InputStream  getInputStream();
OutputStream getOutputStream();
```

- The java.net.ServerSocket:

```
ServerSocket(int port);
Socket       accept();
void         close();
…
```

# Simple sockets demo

- `NetworkServer.java`
- A basic chat system:
  - `TransferThread.java`
  - `TextSocketClient.java`
  - `TextSocketServer.java`

# Higher levels of abstraction

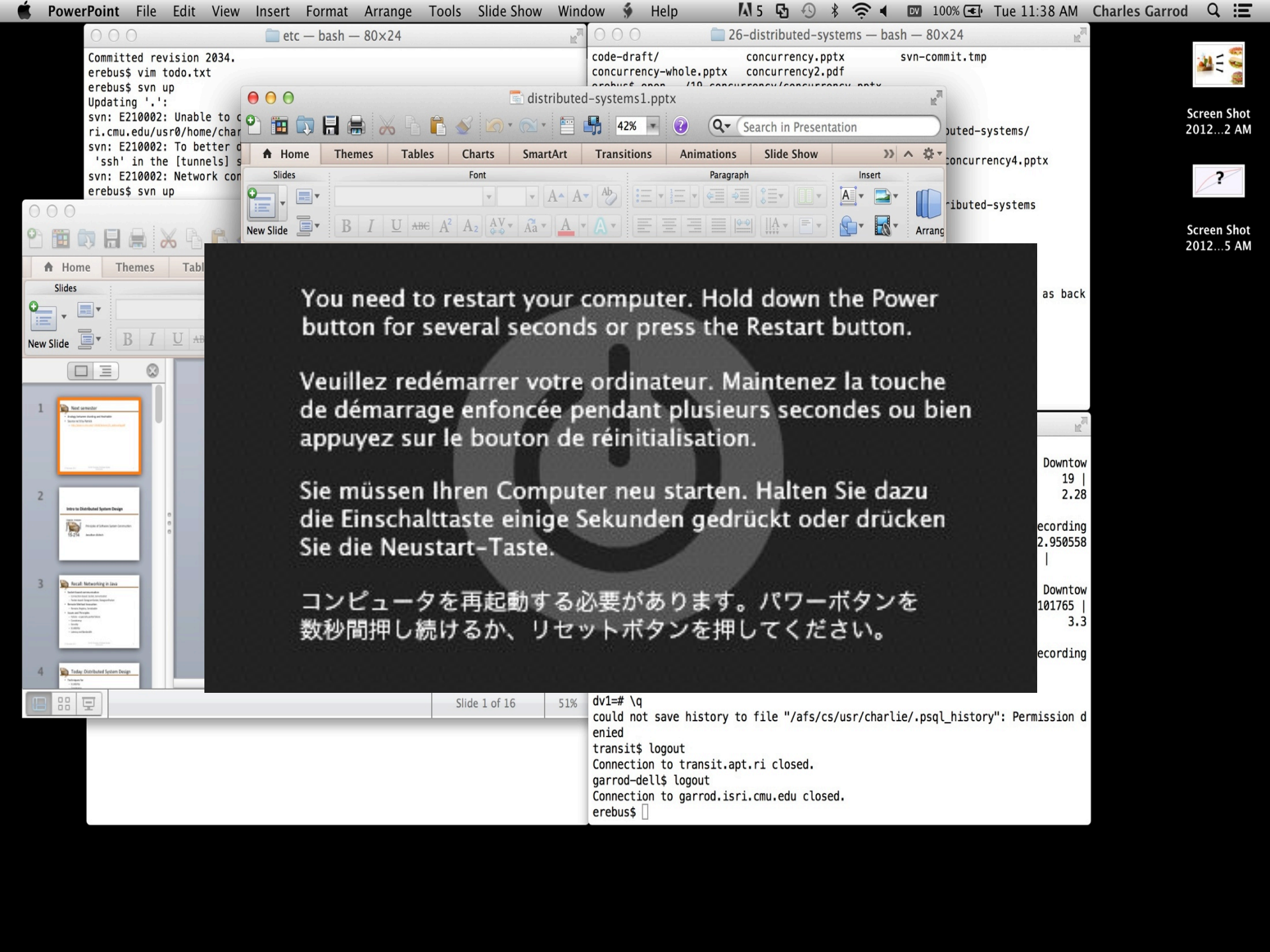
- Application-level communication protocols
- Frameworks for remote computation
  - Remote Procedure Call (RPC)
  - Java Remote Method Invocation (RMI)
- Common distributed system architectures and primitives
  - e.g., distributed consensus, transactions, replication
- Complex computational frameworks
  - e.g., distributed map-reduce

# Today: Distributed system design

- Java networking fundamentals
- Introduction to distributed systems
  - Challenges
  - Motivation: reliability and scalability
  - Failure models

# Metrics of success

- Reliability
  - Often in terms of availability:  fraction of time system is working
    - 99.999% available is "5 nines of availability"
- Scalability
  - Ability to handle workload growth


PowerPoint File Edit View Insert Format Arrange Tools Slide Show Window Help
Tue 11:38 AM Charles Garrod
etc — bash — 80×24
Committed revision 2034.
erebus$ vim todo.txt
erebus$ svn up
Updating '.':
svn: E210002: Unable to c
ri.cmu.edu/usr0/home/char
svn: E210002: To better d
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svn: E210002: Network con
erebus$ svn up
26-distributed-systems — bash — 80×24
code-draft/ concurrency.pptx svn-commit.tmp
concurrency-whole.pptx concurrency2.pdf
distributed-systems1.pptx
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Home Themes Tables Charts SmartArt Transitions Animations Slide Show
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New Slide
You need to restart your computer. Hold down the Power button for several seconds or press the Restart button.
Veuillez redémarrer votre ordinateur. Maintenez la touche de démarrage enfoncée pendant plusieurs secondes ou bien appuyez sur le bouton de réinitialisation.
Sie müssen Ihren Computer neu starten. Halten Sie dazu die Einschalttaste einige Sekunden gedrückt oder drücken Sie die Neustart-Taste.
コンピュータを再起動する必要があります。パワーボタンを数秒間押し続けるか、リセットボタンを押してください。
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51%
dv1=# \q
could not save history to file "/afs/cs/usr/charlie/.psql_history": Permission denied
transit$ logout
Connection to transit.apt.ri closed.
garrod-dell$ logout
Connection to garrod.isri.cmu.edu closed.
erebus$
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Screen Shot 2012...5 AM

# Types of failure behaviors

- Fail-stop
- Other halting failures
- Communication failures
  - Send/receive omissions
  - Network partitions
  - Message corruption
- Data corruption
- Performance failures
  - High packet loss rate
  - Low throughput
  - High latency
- Byzantine failures

# Common assumptions about failures

- Behavior of others is fail-stop (ugh)
- Network is reliable (ugh)
- Network is semi-reliable but asynchronous
- Network messages are not corrupt
- Network failures are transitive
- Failures are independent
- Local data is not corrupt
- Failures are reliably detectable
- Failures are unreliably detectable

# Summary

- Distributed systems are a great source of complexity
  - Abstractions to reduce complexity:
    - Protocols
    - RPC and computational frameworks
    - Common building blocks
- Tuesday: Distributed map reduce