Distributed Systems and Security: An Introduction

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UCL Computer Science

CS GZ03 / M030

29th September 2014

Today's Lecture

- Administrivia
- Overview of Distributed Systems
  - What are they?
  - Why build them?
  - Why are they hard to build well?
- Operating Systems Background
- Questionnaire

Prerequisites

- Undergraduates: must have taken UCL CS 3035, Networked Systems, or equivalent experience (3rd-year undergrad networking class, covering Internet protocols and architecture in depth)
- Graduates: must be concurrently enrolled in UCL CS GZ01, Networked Systems, or equivalent prior experience (3rd-year undergrad networking class, covering Internet protocols and architecture in depth)

Course Staff and Office Hours

- Instructor:
  - Brad Karp, MPEB 7.20, Wed 4 – 5 PM, ext. 30406
- Teaching Assistant:
  - Katrina Joyce, MPEB 7th floor lab,
    Tue 5:45 – 6:45 PM, ext. 30398
- Office hours begin this Tuesday
- Time reserved for answering your questions
- Outside office hours, email to schedule appointment

Meeting Times and Locations

- Mondays 5 PM – 7 PM,
  room varies; see class calendar on web site
- Wednesdays 9 AM – 11 AM,
  MPEB, Room 1.02
- Lecture will run 90 minutes
  - Monday lectures will usually end at 6:30 PM
  - Wednesday lectures will usually begin at 9:30 AM
- Occasionally lecture will be followed by a 30-minute discussion of an additional topic (e.g., Q&A on a coursework); on these dates, full two hours!
- No lecture 6th, 8th, 27th, 29th October; 26th November
- Reading week: 3rd – 7th November, no lecture!

Class Communication

- Class web page
  - http://www.cs.ucl.ac.uk/staff/B.Karp/gz03/f2014/
  - Detailed calendar, coursework, class policies
  - **Your responsibility: check page daily!**
- M030/GZ03 Piazza Page
  - https://piazza.com/ucl.ac.uk/fall2014/computersciencem030gz03/home
  - Important announcements from class staff (also forwarded to you by email)
  - Postings from course staff and students
  - Subscribe using enrollment key
  - You **must** subscribe (class policy)
  - **Your responsibility: check email daily!**

Using Piazza

- Please post questions on class material on Piazza, rather than emailing course staff
- Whole class benefits from seeing your question and its answer
- Students are encouraged to answer one another's questions!
- When discussing something private (e.g., your marks, or details of your specific solution to a coursework), mark your post as **private**, so only course staff see it!

Readings, Lectures, and Lecture Notes

- Readings must be read before lecture; lectures **assume you have done so**
- Lecture notes will be posted to the class web site just after lecture
- Class calendar shows all reading assignments day by day…

Readings

- No textbook
- Classic and recent research papers on real, built distributed and secure systems
- Available on class web page; print these yourselves
- All readings examinable
- Research papers are dense and complex; they are often challenging
  - Be prepared to read and re-read the papers
  - Come to lecture with questions, and/or use office hours

Grading

- Final grade components:
  - One programming coursework: 15%
  - One problem set coursework: 15%
  - Final exam: 70%

Late Work Policy

- N.B. that **M030/GZ03 policy differs from that for other CS classes!**
- For every day late or fraction thereof, **including weekend days,** 10% of marks deducted
- Each student receives budget of **3 late days** for entire term
  - Each late day "cancels" one day of lateness
  - Goal: give you flexibility, e.g., in case you can't find a bug, or encounter unexpected other snag
  - You declare how many late days to use when turning in a coursework late; cannot declare or change later!
  - Must use whole late days—cannot use fractional ones!

Late Days (cont'd)

- If submission more than 2 days late after taking late days into account, zero marks
- Programming courseworks turned in online; may be submitted 24/7
- Problem set courseworks turned in on paper in lecture; can be submitted M – F only
  - Weekend days after deadline still count as elapsed days

Late Days (cont'd)

- If submission more than 2 days late after taking late days into account, zero marks

Late days give you flexibility.
No other extensions given on coursework, unless for unforeseeable, severely extenuating circumstances!

paper in lecture; can be submitted M – F only
  - Weekend days after deadline still count as elapsed days

Academic Honesty

- All courseworks must be completed individually
- May discuss understanding of problem statement, general sketch of approach
- May not discuss details of solution
- May not show your solution to others (this year or in future years)
- May not look at others' solutions (this year or from past years)

Academic Honesty (cont'd)

- We use code comparison software
  - Compares parse trees; immune to obfuscation
  - Produces color-coded all-student-pairs code comparisons
- Don't copy code—you **will** be caught!
- Penalty for copying: automatic zero marks, referral for disciplinary action by UCL (usually leads to exclusion from all exams at UCL)

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What Is a Distributed System?

- Multiple computers ("machines," "hosts," "boxes," *&c.*)
  - Each with CPU, memory, disk, network interface
  - Interconnected by LAN or WAN (*e.g.,* Internet)
- Application runs across this dispersed collection of networked hardware
- But user sees single, unified system

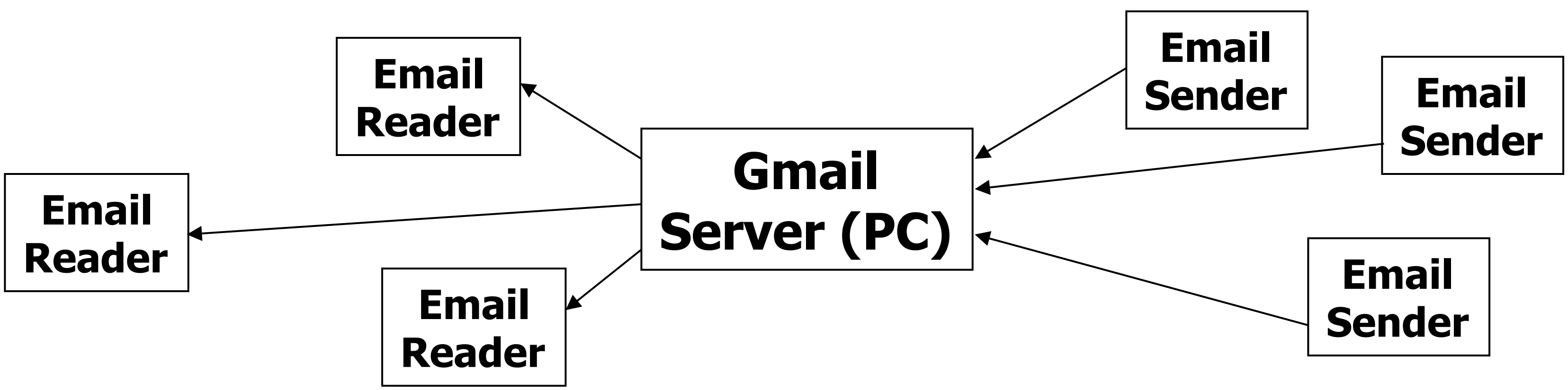
What Is a Distributed System? (Alternate Take)

"A distributed system is a system in which I can't do my work because some computer that I've never even heard of has failed."

– Leslie Lamport, Microsoft Research (ex DEC)

Start Simple: Centralized System

- Suppose you run Gmail
- Workload:
  - Inbound email arrives; store on disk
  - Users retrieve, delete their email
- You run Gmail on one server with disk

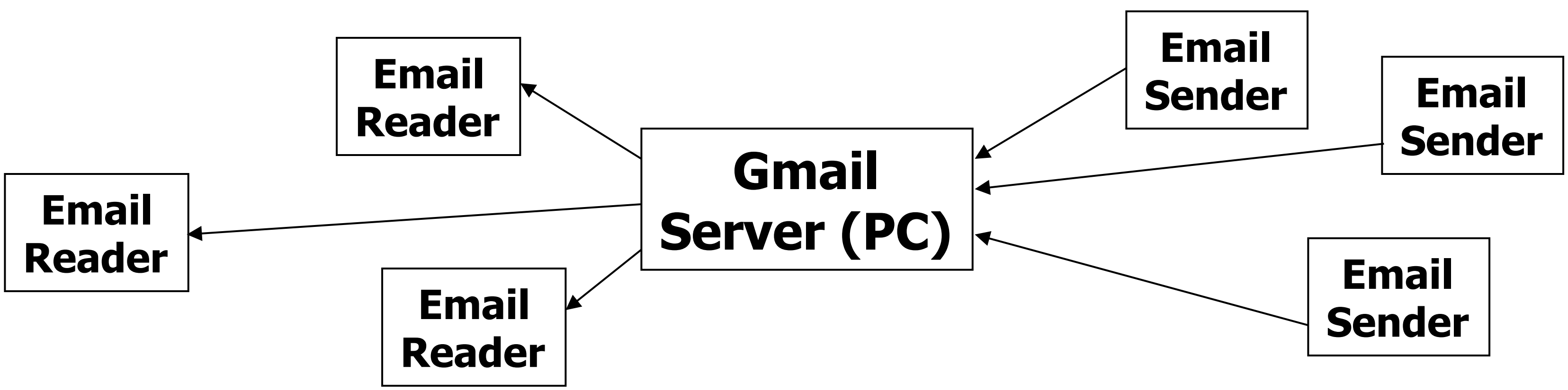


Start Simple: Centralized System

- Suppose you run Gmail
- Workload:

What are shortcomings of this design?

- You run Gmail on one server with disk



Why Distribute? For Availability

- Suppose Gmail server goes down, or network between client and it goes down
- No incoming mail delivered, no users can read their inboxes
- Fix: replicate the data on several servers
  - Increased chance some server will be reachable
  - Consistency? One server down when delete message, then comes back up; message returns in inbox
  - Latency? Replicas should be far apart, so they fail independently
  - Partition resilience? *e.g.,* airline seat database splits, one seat remains, bought twice, once in each half!

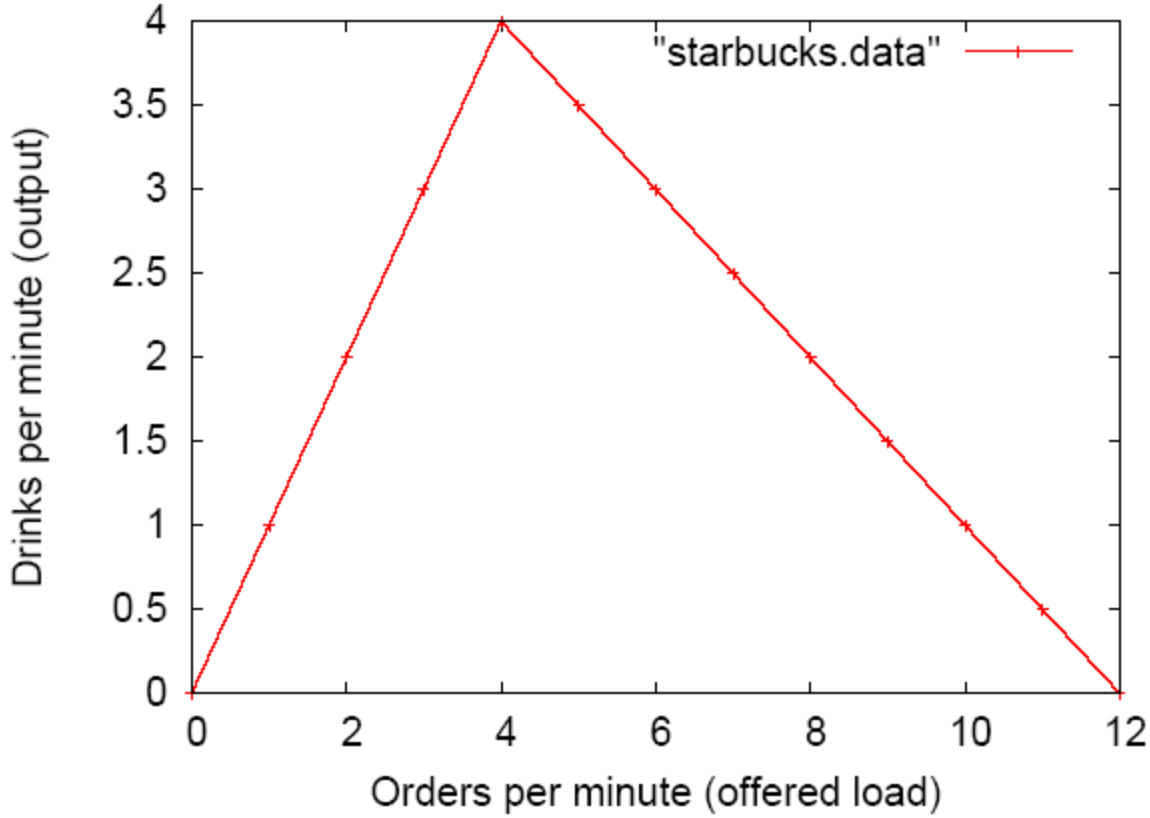
Why Distribute?
For Scalable Capacity

- What if Gmail a huge success?
- Workload exceeds capacity of one server
- Fix: spread users across several servers
  - Best case: linear scaling—if *U* users per box, *N* boxes support *NU* users
  - Bottlenecks? If each user's inbox on one server, how to route inbound mail to right server?
  - Scaling? How close to linear?
  - Load balance? Some users get more mail than others!

Performance Can Be Subtle

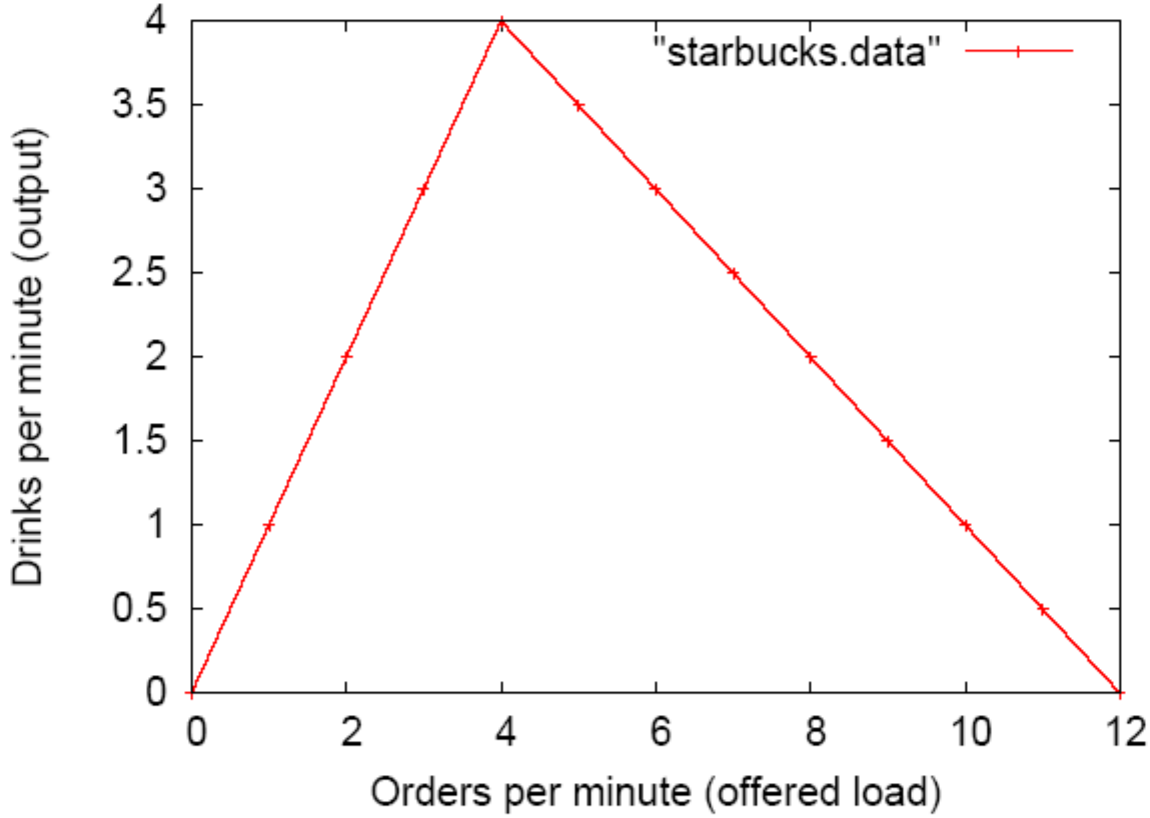
- Goal: predictable performance under high load
- 2 employees run a Starbucks
  - Employee 1: takes orders from customers, calls them out to Employee 2
  - Employee 2:
    - writes down drink orders (5 seconds per order)
    - makes drinks (10 seconds per order)
- What is throughput under increasing load?

Starbucks Throughput



- Peak system performance: 4 drinks / min
- What happens when load > 4 orders / min?
- What happens to efficiency as load increases?

Starbucks Throughput



What would preferable curve be?
What design achieves that goal?

Why Are Distributed Systems Hard to Design?

- Failure: of hosts, of network
  - Remember Lamport's lament
- Heterogeneity
  - Hosts may have different data representations
- Need consistency (many specific definitions)
  - Users expect familiar "centralized" behavior
- Need concurrency for performance
  - Avoid waiting synchronously, leaving resources idle
  - Overlap requests concurrently whenever possible

Security

- Before Internet:
  - Encryption and authentication using cryptography
  - Between parties known to each other (e.g., diplomatic wire)
- Today:
  - Entire Internet of potential attackers
  - Legitimate correspondents often have no prior relationship
  - Online shopping: how do you know you gave credit card number to amazon.com? How does amazon.com know you are authorized credit card user?
  - Software download: backdoor in your new browser?
  - Software vulnerabilities: remote infection by worms!
  - Crypto not enough alone to solve these problems!