(Q) Describe: ...

An Introduction to
Distributed Systems
SCC 311

(Q) Describe: Overview of the Session

1 Overview of the Session

What is a distributed system?
Examples of distributed systems
Why distributed systems?
Historical distributed systems
Recent trends in distributed
systems

(Q) Describe: What is a System?

2 What is a System?

A collection of hardware and software.

"A computer system consists of hardware and systems software that work together to run application programs."
Bryant and O'Hallaron

(Q) Describe: Tour of a Computer System

3 Tour of a Computer System

Registers, L1/L2/L3 caches, RAM, local disk, remote disk
A memory hierarchy
CPU running instructions
Carnegie Mellon
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Example Memory
Hierarchy Regs
L1 cache
(SRAM)
Main memory
(DRAM)
Local secondary storage
(local disks)
Larger,
slower,
and
cheaper
(per byte)
storage
devices
Remote secondary storage
(e.g., Web servers)
Local disks hold files
retrieved from disks
on remote servers.
L2 cache
(SRAM)
L1 cache holds cache lines
retrieved from the L2 cache.
CPU registers hold words retrieved
from the L1 cache.
L2 cache holds cache lines
retrieved from L3 cache.
L0:
L1:
L2:

L3:
L4:
L5:
Smaller,
faster,
and
costlier
(per byte)
storage
devices
L3 cache
(SRAM)
L3 cache holds cache lines
retrieved from main memory.
L6:
Main memory holds disk
blocks retrieved from local
disks.
Carnegie Mellon
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I/O Bus
Main
memory
I/O
bridgeBus interface
ALU
Register file
CPU chip
System bus Memory bus
Disk
controller
Graphics
adapter
USB
controller
Mouse Keyboard Monitor
Disk
I/O bus Expansion slots for

other devices such
as network adapters.

(Q) Describe: Tour of a Computer System

4 Tour of a Computer System

Registers, L1/L2/L3 caches, RAM, Disk
memory hierarchy
CPU with multiple cores
Operating system
Files, threads, . . .
Assembly code
Compilers
Programs

(Q) Describe: What is a Distributed System?

5 What is a Distributed System?

"a collection of independent computers that appears to its users as a single coherent system"
Tanenbaum and van Steen

"one in which hardware or software components located at networked computers communicate and coordinate their actions only by passing messages"
Coulouris, Dollimore, Kindberg

"one that stops you getting work done when a machine you've never even heard of crashes"
Lamport

(Q) Describe: “a system designed to support the development of

6 "a system designed to support the development of

applications and services which can exploit a physical architecture consisting of multiple autonomous processing elements that do not share primary memory but cooperate by sending asynchronous messages over a communications network"

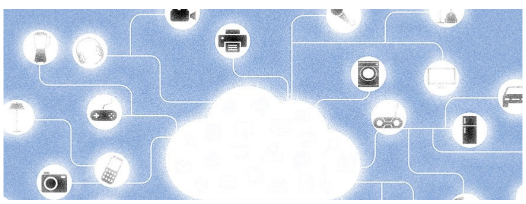
Blair and Stefani, 1998

What is a Distributed System?

(Q) Describe: In its broadest definition, a distributed system is one that

7 In its broadest definition, a distributed system is one that

comprises more than one computer with the goal of
reaching a level of performance and/or providing a
service that is quite difficult or infeasible to do on a single
computer.
What is a Distributed System?



(Q) Describe: Examples of Distributed Systems

8 Examples of Distributed Systems

Financial trading
Support execution of trading transactions
Dissemination and processing of events
Web search
The web consists of over 6 billion web pages across 8.2 million servers with an average lifetime of about 2 months.
Modern web engines serve over 3.5 billion searches per day
>Major distributed systems challenges
Massively multiplayer online games
Online games (e.g. Fortnite, Among Us) support large numbers of users viewing and changing a common world
Need for very low latency coordination to support gameplay

(Q) Describe: Why Distributed Systems?

9 Why Distributed Systems?

Because the world is distributed
You want to book a hotel in Sydney, but you are in Lancaster
You want to be able to retrieve money from any ATM in the world, but your bank is in London
An airplane has 1 cockpit, 2 wings, 4 engines, 10k sensors, etc.
0 Similarly railway networks, and other distributed transport systems
Because problems rarely hit two different places at the same time
As a company having only one database server is a bad idea
Having two in the same room is better, but still risky
Because joining forces increases performance, availability, etc.
High Performance Computing, replicated web servers, etc.

(Q) Describe: Why Distributed Systems?

10 Why Distributed Systems?

DISTRIBUTED SYSTEMS

acmqueue There's Just No Getting around It: You're Building a Distributed System

Building a distributed system requires a methodical approach to requirements

Mark Cavage

Distributed systems are difficult to understand, design, build, and operate. They introduce exponentially more variables into a design than a single machine does, making the root cause of an application problem much harder to discover. It should be said that if an application does not have meaningful SLAs (service-level agreements) and can tolerate extended downtime and/or performance degradation, then the barrier to entry is greatly reduced. Most modern applications, however, have an expectation of resiliency from their users, and SLAs are typically measured by "the number of nines" (e.g., 99.9 or 99.99 percent availability per month). Each additional 9 becomes harder and harder to achieve.

(Q) Describe: Is this important?

11 Is this important?

CLOUD

The Cloud team provides fundamental technology solutions around the automation and orchestration of continuous delivery pipelines targeting public cloud infrastructure.

MEDIA DISTRIBUTION

The Media Distribution team develops the software for geographically distributed caching servers that deal with the high throughput, high concurrency and low latency requirements of delivering BBC content to the audiences. If you've used iPlayer, there's a high likelihood that what you watched came from the in-house CDN that this team has developed.

facebook

Summary:

Facebook is seeking an experienced Software Engineer to join the Software Engineering (Infrastructure) team. The Software Engineering (Infrastructure) team builds large distributed components that run Facebook. Our code serves millions of requests per second and it does so with sub-second latency and in a fault tolerant manner. We handle everything from Facebook scale data storage, to synchronization and coordination of large server clusters, to providing a runtime environment for front end Facebook code. We are looking for candidates who share a passion for tackling complexity and building platforms that can scale through multiple orders of magnitude. This position is full-time and is based in our main office in New York, NY.

NETFLIX

BACK TO RESULTS | Engineering | Cloud and Platform Engineeri

THE OPPORTUNITY

We are looking for an outstanding Senior Software Engineer to help tackle the exciting technical opportunities ahead. You'll be joining a great team that develops core Platform infrastructure used by over 200 microservices at Netflix and handles hundreds of billions of operations per day.

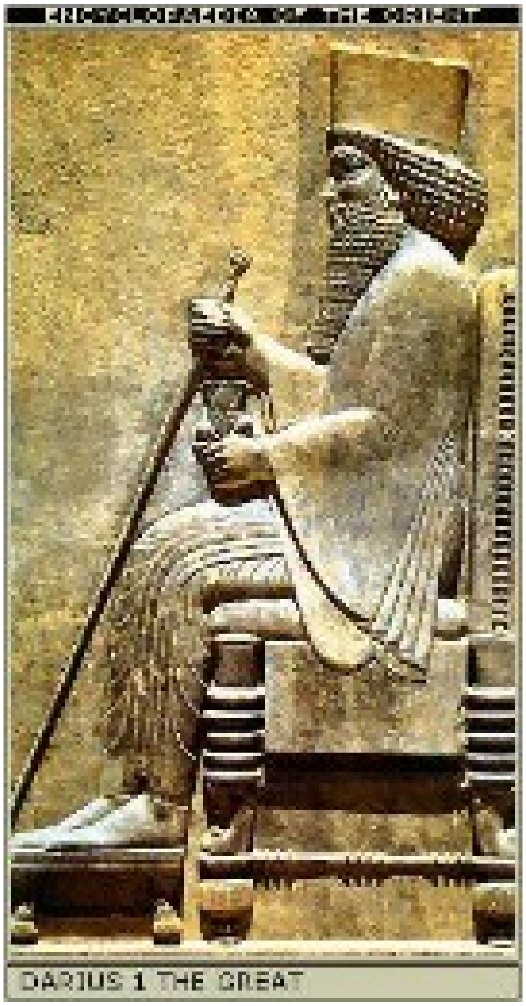
Our team has a relatively broad mandate that encompasses business logic, distributed processing, Publish-Subscribe messaging, system insight, tooling, and beyond.

BBC

(Q) Describe: A Short History of DSs

12 A Short History of DSs

Distributed Computer Systems are largely concerned with:
Data processing/ management/ presentation ("computing" side)
Communication/ coordination ("distributed side")
Those concerns existed well before computers were invented
Ancient civilisations needed efficient communication:
0 cf. the Postal Service of the Persian Empire (6th century BC), the Roman roads (many still visible today), etc.
0 assuming a good infrastructure (roads, horses, staging posts)
0 max message speed: ~200 miles/day in the Persian system
Delays impose distributed organisations
0 Persian and Roman empires extended over 1000s of miles
Trust / secrecy / reliability issues
0 Am I sure Governor X is doing what he says he is?
This all has not really changed!
Things have only sped up.



DARIUS 1 THE GREAT

(Q) Describe: A Short History of DSs

13 A Short History of DSs

Computers are far more recent
The first “modern” computers appeared just after WWII
They were slow, bulky, and incredibly expensive
0 The ENIAC (1945), used by the US army: 30 tons, 170 m2 footprint,
180 kilowatts, 18,000 vacuum tubes, and 5,000 additions/second (5KHz),
0 Price: $500,000 (in US$ of the time, would be >$5,000,000 today)
And distributed computing is even more recent
For a long time, only very few computers were around anyway
No practical technology to connect them
This all changed in the 80’s:
0 The rise of the micro-computers (PC, Mac, etc.)
0 The launch of the “Internet” (1982, TCP/IP), after 10 years of development
1940s 50s 60s 70s 80s 90s 00s 10s 20s
Fir
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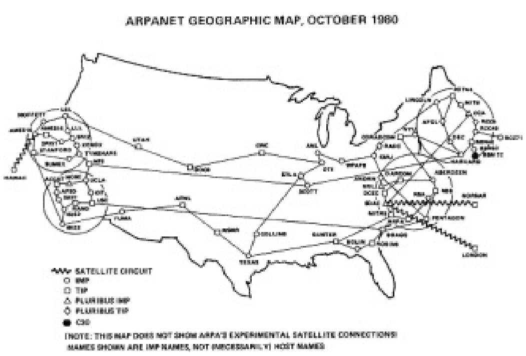
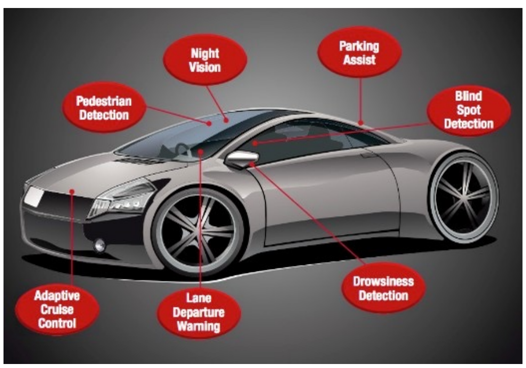
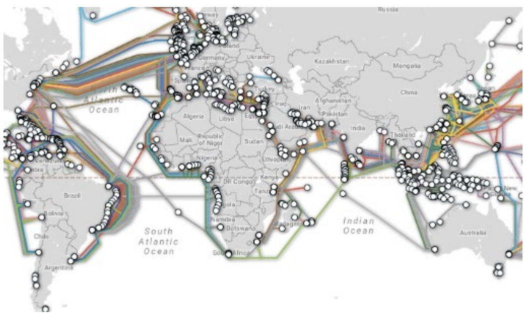

ARPANET GEOGRAPHIC MAP, OCTOBER 1980
SATELLITE CIRCUIT
IMP
TIP
PLURIBUS IMP
PLURIBUS TIP
C30
(NOTE: THIS MAP DOES NOT SHOW ARPA'S EXPERIMENTAL SATELLITE CONNECTIONS)
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

(Q) Describe: Recent Trends

14 Recent Trends

Pervasive networking and the modern Internet
Highly heterogeneous networking technologies
Fusion of services (telephony, broadcasting. . .)
Mobile and ubiquitous computing
Personal devices and embedded systems
Distributed multimedia systems
IPTV and Voice over IP services
Distributed computing as a utility
Grid, Cloud, and Fog computing
The pace of change is accelerating

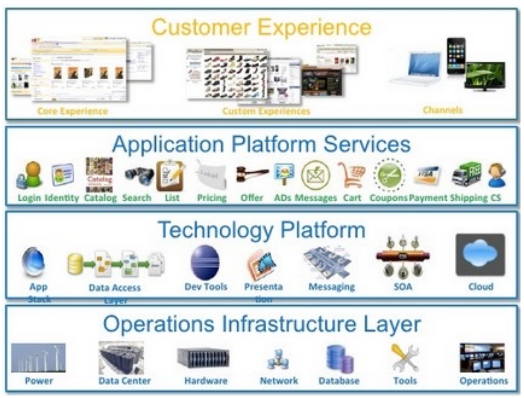


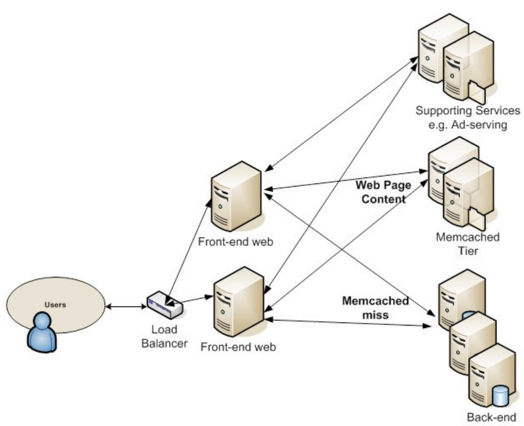

Russia
Kazakhstan
Mongolia
China
Ukraine
Germany
Turkey
Afghanistan
Iran
Pakistan
India
Thailand
Algeria
Libya
Mali
Republic of Niger
Sudan
Nigeria
Ethiopia
Kenya
Namibia
Brazil
Bolivia
Chile
Argentina
Australia
South Atlantic Ocean
Indian Ocean

(Q) Describe: Interactions

15 Interactions

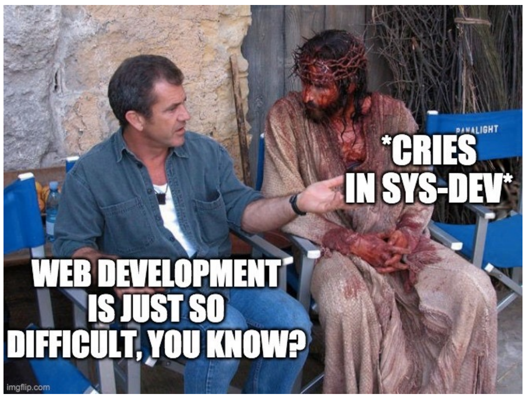
What sort of interactions do we expect?
Web
Client: “I want this thing”
Server: “Here’s the thing”
eBay
Alice: “I bid £10”
Bob: “I bid £12”
eBay: “Alice wins. Bob was late”
More on design patterns later (week 4).





(Q) Describe: Is this easy?

16 Is this easy?



(Q) Describe: But why is this so hard?

17 But why is this so hard?

A bank asks you to program their new ATM software
Central bank computer (server) stores account information
Remote ATMs authenticate customers and deliver money
A first version of the program
ATM: (ignoring authentication and security issues)
1. Ask customer how much money s/he wants
2. Send message with <customer ID, withdraw, amount >to bank server
3. Wait for bank server answer: <OK >or <refused >
4. If <OK >give money to customer, else display error message
Central Server:
1. Wait for messages from ATM: <customer ID, withdraw, amount >
2. If enough money withdraw money, send <OK >, else send <refused >

(Q) Describe: ATM Bank Server

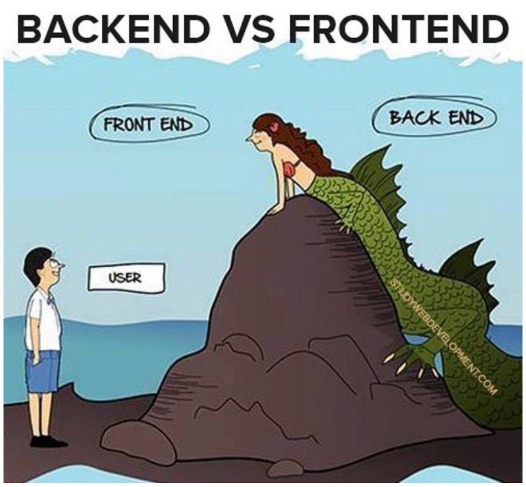
18 ATM Bank Server

John: £500
But ...
What if the bank server crashes just after 2 and before 3?
What if the <OK >message gets lost? Takes too long to arrive?
What if the ATM crashes after 1, but before 4?
More on challenges in coming lectures.
<John, withdraw, £200 >
1
John: £300
-£200 2
<OK >
3
4
But why is this so hard?


Geldautomat

(Q) Describe: Is this easy?

19 Is this easy?



(Q) Describe: Expected Learning Outcomes

20 Expected Learning Outcomes

At the end of this session, you should be able to:
Define distributed computer systems
Explain why distribution is needed
Know a few everyday examples of distributed systems
Understand how they evolved into their current form

(Q) Describe: Additional Reading

21 Additional Reading

Required: CDKB, chapter 1 sections 1.1 – 1.4
also chapter 3 for revision
TvS, chapter 1
Computer Systems: A Programmer's Perspective, by Bryant and O'Hallaron, chapter 1
Mark Cavage, "There's Just No Getting around It: You're Building a Distributed System", ACM Queue, Vol. 11 No. 4, April 2013. http://queue.acm.org/detail.cfm?id=2482856

(Q) Describe: ...

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