



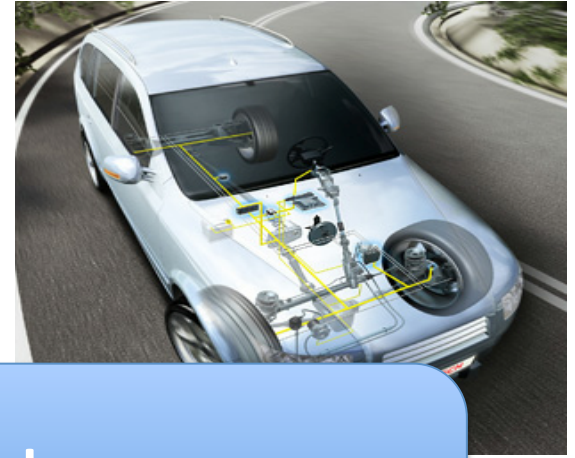
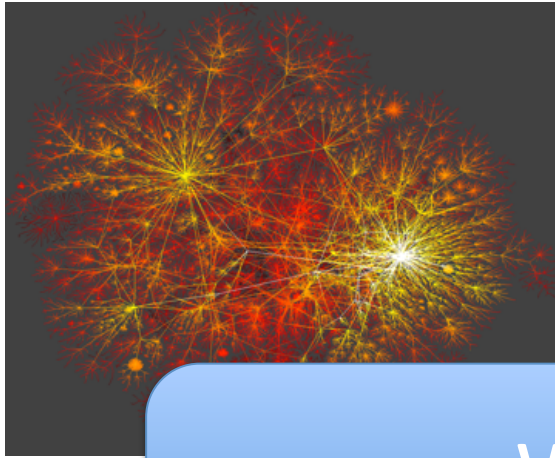
Networks and Distributed Systems

Olaf Landsiedel

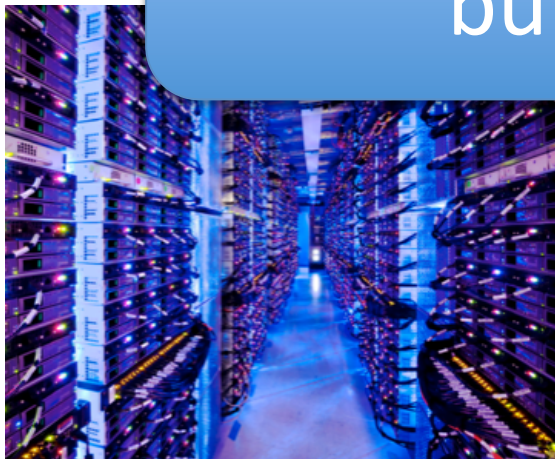
Definition

- I believe you know what a network is...
- But, what is a **Distributed System**?
 - Have you ever seen one?
 - Have you ever used one?
- A Distributed System is characterized by?
 - Multiple devices
 - Connected by a network
 - Cooperating on some task

Examples



We teach you how to
build large-scale systems

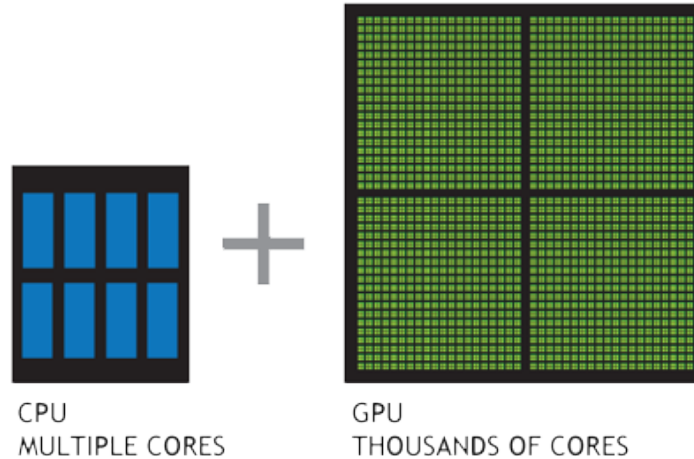


Cloud Computing / Data Center

Phone Network

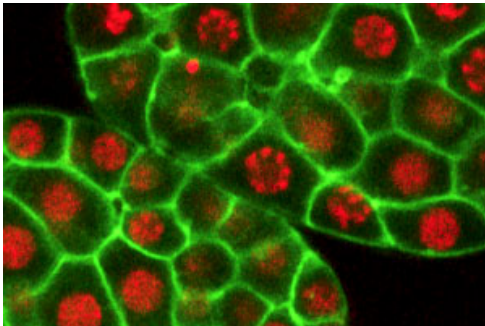
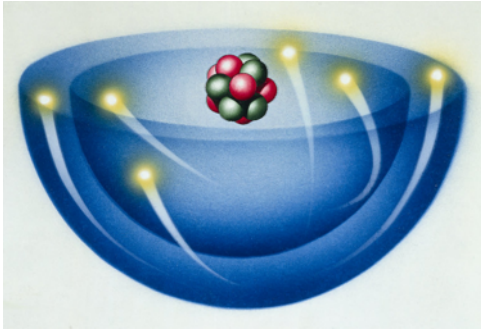
Power Grid

One more Example



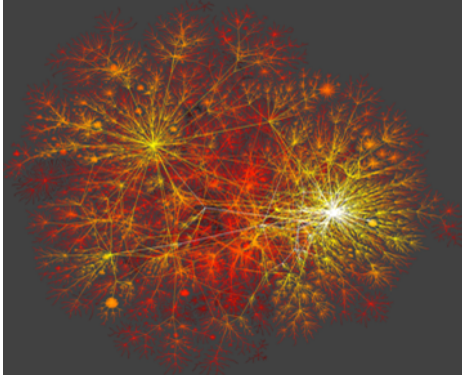
- A modern computer is a distributed system
 - Multi-core CPU
 - Multi-core GPU
 - ...
- Actually
 - Even a modern cell phone

Note



- Non computer-driven “distributed systems”
 - Atoms
 - Molecules
 - Society
 - Animals (ants, bees, ...)
 - ...
- Not topic of our lectures

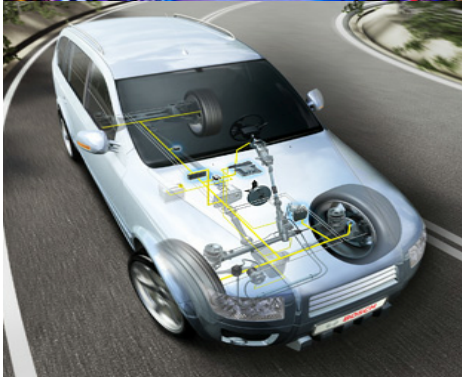
Distributed Systems vs. Networks



- Networking is worried about
 - Sending a message from here to there
 - Not what you do with the message



- Distributed Systems
 - Assume:
 - There is a way to send messages
 - Focus: How you build a system using those messages
 - **Teach you what things to do with a network**



COURSES

Computer Systems and Networks

120 credits (MSc, 2 years)

Distributed Systems Profile

<https://www.chalmers.se/en/education/programmes/masters-info/Pages/Computer-systems-and-networks.aspx>

Programme Curriculum Career and Research Media News

Computer Systems and Networks

120 credits (MSc, 2 years)

Programme aim

As a student of this master's programme, you will develop a solid grasp of computer systems and networks through a broad, yet in-depth, training experience in the field of Computer Science and Engineering.

You will acquire theoretical knowledge and engineering skills in:

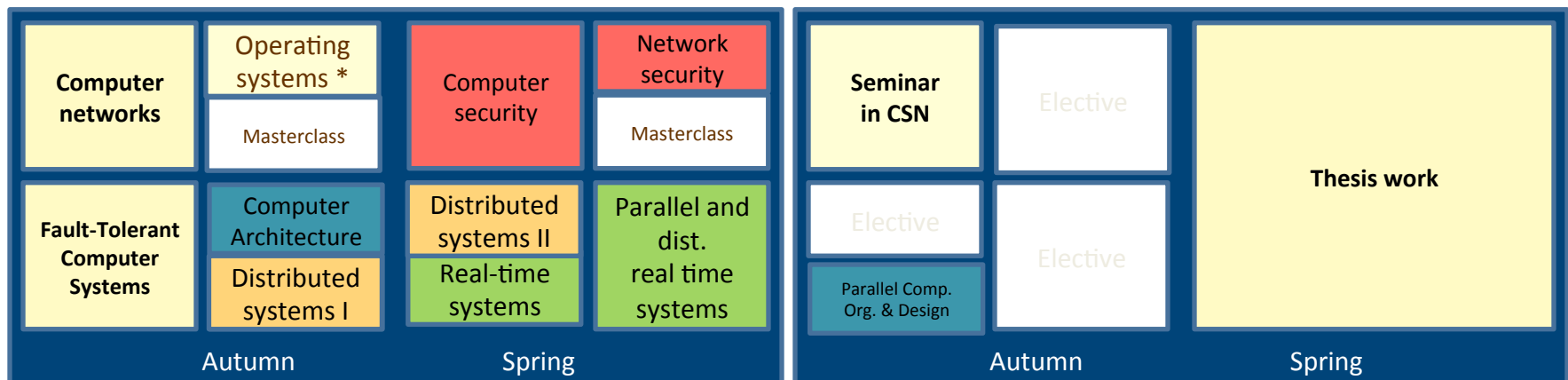
- Parallel and Distributed Systems
- Computer Security and Dependability
- Computer Systems Engineering
- Communication Networks



Computer Systems and Networks

120 credits (MSc, 2 years)

Distributed Systems Profile



Also available as
elective courses
from other
programs

Course Goals in a Nutshell

- Lectures: Teach you Distributed Systems
 - What do they do?
 - How do they work?
- Labs: Give you hands-on experience
 - Feel the challenges
 - Master the techniques
- Have some fun!
 - Optional: you can pass without it

Will I learn something useful?

- We hope so!
 - This our key goal
- From an email we got from a former student
 - “[...] I'm [...] making a living out of building distributed systems, [...] rest assured I've been finding the contents of your course very useful. :)”
 - Started working at Spotify
- We hope you will have a similar experience

More courses

- **Distributed Systems:**
 - **Distributed Systems**, LP2, 7.5hec(hp), TDA596 (Chalmers), DIT240 (GU)
 - **Distributed Systems advanced (Distribuerade system fk.)**, LP3 – 7.5 hec (hp), TDA297 (CTH), DIT290 (GU)
- **Project Courses**
 - DAT295 - **Autonomous and Cooperative Vehicular Systems**, Lp2, 7.5hec
 - DAT300 - **ICT support for adaptiveness and security in the smart grid**, LP4, 7.5hec
- **Broader Field**
 - EDA387 - **Computer networks**, LP1, 7.5 hec
 - EDA343, EDA344, LEU061 **Datakommunikation**, LP1, LP3, LP4. 7.5 hec
 - EDA491 - **Network security**, LP4, 7.5 hec

HISTORY

History

- In the examples
 - Many different distributed systems
- How did we get here
 - Where do all these DSs come from?
 - What is the trend?
 - Will their number increase even more?

1943

I think there is
a world market
for maybe five
computers



Thomas J. Watson, 1943;
Chairman and CEO of
International Business
Machines (IBM)

Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

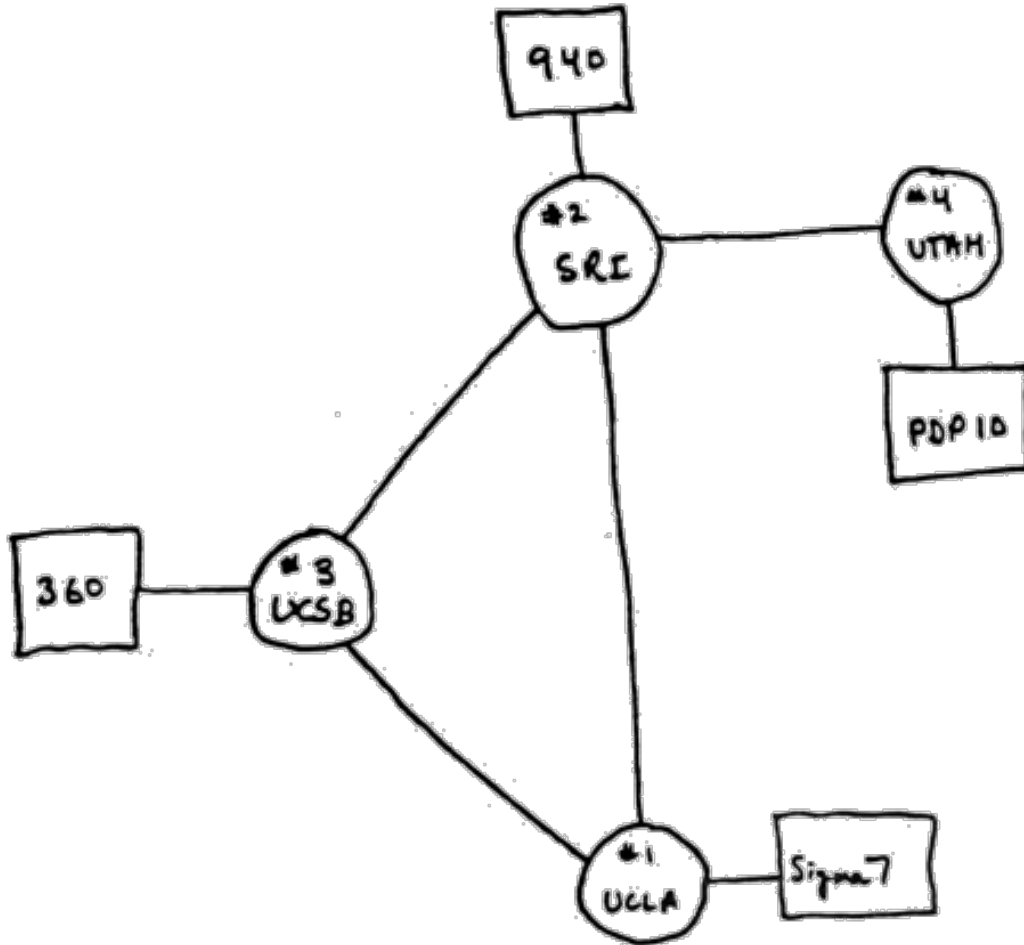
1992

1993

1994



1969



Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

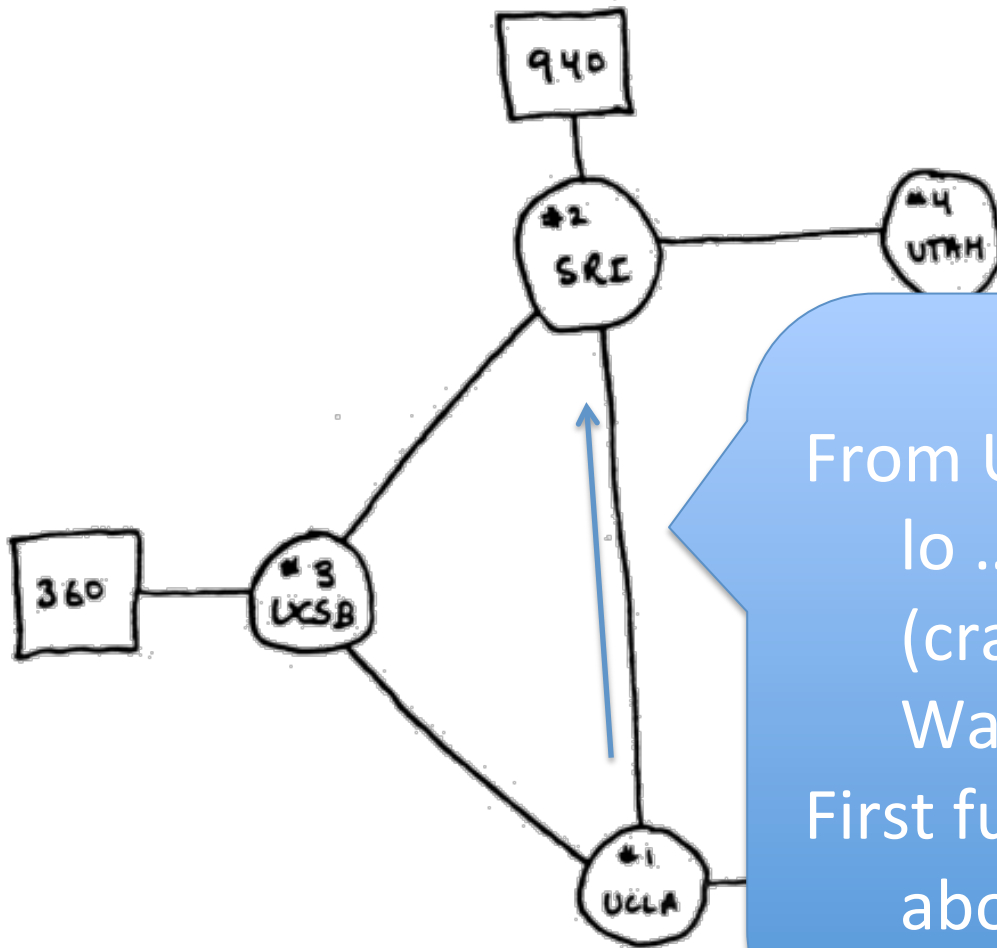
1993

1994

ARPANET begins...with a deployment at UCLA, Stanford, UCSB, and Utah (one computer per site)

1969, 29 Oct, 22:30: First data on the Internet

- Pre-me (<1979)
- Pre-you (<1989)
- 1989
- 1990
- 1991
- 1992



From UCLA to SRI:
lo ...
(crash of SRI machine)!
Wanted to send “login”
First full-login:
about one hour later

1969, 29 Oct, 22:30: First data on the Internet

Pre-me (<1979)

Pre-you (<1989)

1989

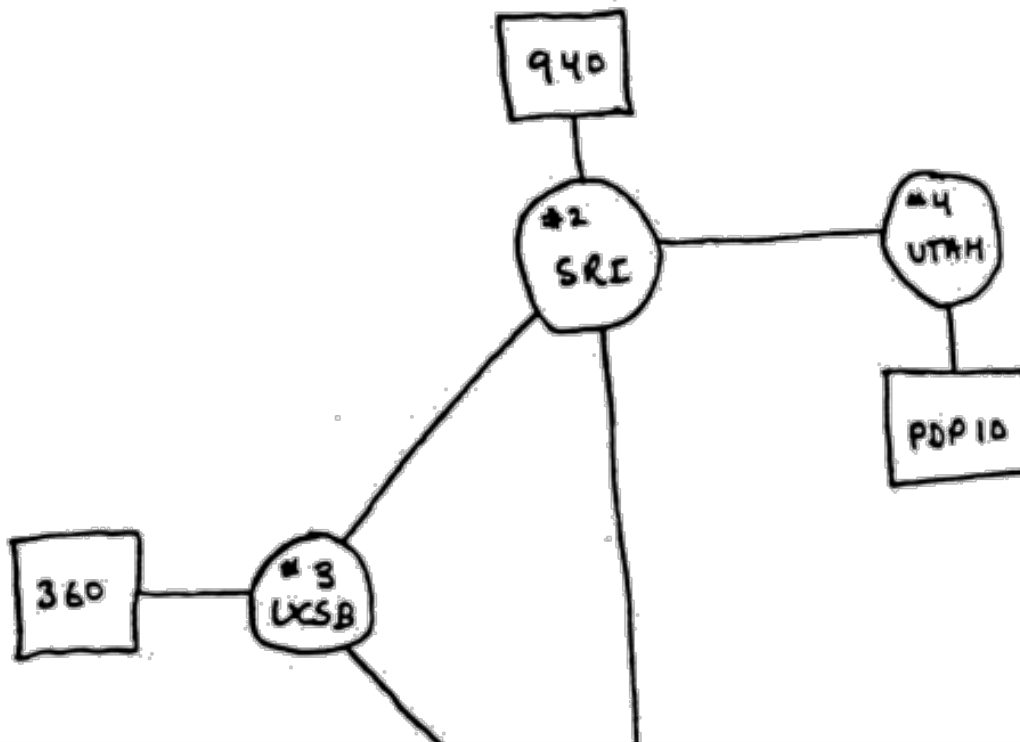
1990

1991

1992

1993

1994

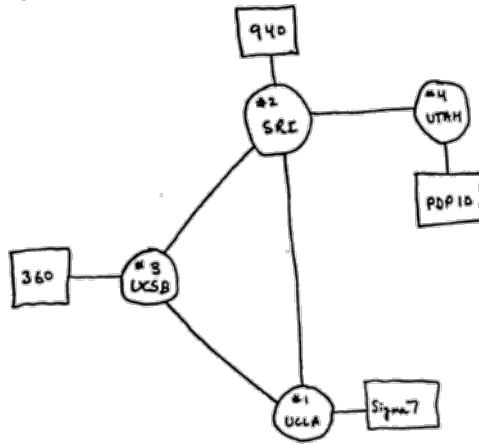


Lessons Learned:

1. First words/letters on the Internet: "lo"
2. Not many things in the Internet work on the first try

1977

1969 →



Pre-me (<1979)

Pre-you (<1989)

1989

1990

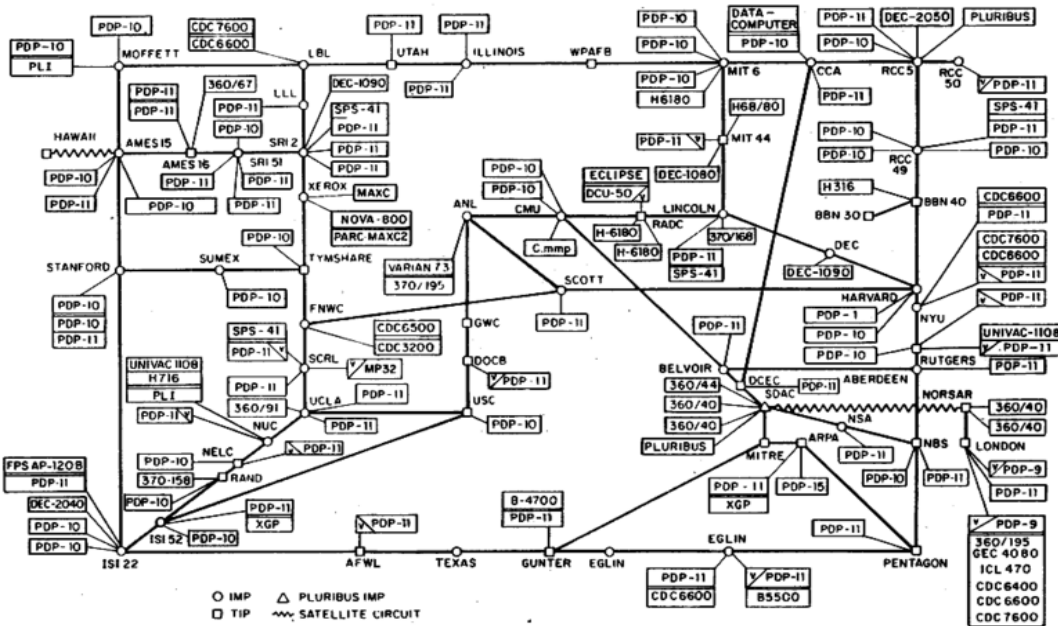
1991

1992

1993

1994

ARPANET LOGICAL MAP, MARCH 1977



(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE MOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

NAMES SHOWN ARE IMP NAMES, NOT NECESSARILY HOST NAMES

← 1977



World Internet Topology

Brought to you by **AT&T Labs**

Powered by **LUMETA**

This map represents the backbone of the Internet as of August 2007. Each line depicts the shortest outgoing route from a host computer to each of more than 320,000 network nodes around the world. The map does not represent the physical or geographic location of servers, but rather is a topological representation of the various networks that comprise the Internet.

It shows the tensible number of interconnected networks owned and maintained by private companies. These networks combine to form the world's Internet backbone. This map is a product of the Internet Mapping Project, it was compiled and created by Bill Chewick and Steven South at AT&T Labs Research, using technology and methods developed by the Lumeta Corporation.

AT&T's Network by the Numbers.

9.81
Petabytes of data transmitted across AT&T's networks on an average business day. It is the equivalent of moving the entire written contents of the Library of Congress every three minutes.

1
AT&T's rank among broadband providers in the United States.

12.9 Million
AT&T broadband customers in America.

540,000
Miles of Internet backbone fiber AT&T owns and operates.

\$6 Billion
Amount AT&T will spend by 2008 to bring fiber optics deeper into neighborhoods.

36
AT&T Internet data centers around the world.

301,760
AT&T employees worldwide.

97%
Percentage of the world economy reached by AT&T's networks.

99.998%
AT&T's network reliability.

49,000
Number of Wi-Fi hotspots AT&T provides or enables.

166
Number of United States cities where AT&T offers 3G wireless High-Speed Internet access.

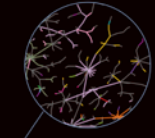
3 Million
AT&T wireless business data subscribers.

160%
Increase in bandwidth demand per AT&T user between June 2004 and October 2006.

7
Nobel Prizes awarded for innovations developed at the AT&T Bell Labs.

2
Average number of new patent applications AT&T files - every day.

■ AT&T ■ Time Warner ■ SBCNETS ■ China Telecom ■ NetNet ■ High Media
■ Bell Canada ■ WorldCom ■ Sprint ■ Orange Communications ■ NetScout ■ High Media
■ TCI ■ Cogent ■ Tritel ■ Tritel ■ Global Crossing ■ Global Crossing
■ Cogent ■ Cogent ■ Tritel ■ Global Crossing ■ Global Crossing ■ Global Crossing



These clusters represent Internet service provider network hubs. Each cluster represents a server-provided system of connecting thousands of individual users to the Internet. The topology of the smaller branches are more difficult to define; they may represent a server, another router, or even a server rack, router.

World Internet by the Numbers.

More than **320,000**
Individual network nodes found by the Internet Mapping Project.

48 Million
Users on the Internet in 1995.
(Source: ICS)

1.133 Billion
Internet users in 2006.
(Source: Internet World Watch)

6.4 Million
New Internet users getting online every month.
(Source: Internet World Watch)

1.6 Billion
Email boxes in use in 2006.
(Source: ICS)

40 Million
New DNS Hosts every year.
(Source: Internet Systems Consortium)

35,000
Web pages a minute to equal the amount of data transferred when a user downloads 1 HD movie.
(Source: Cnet Network)

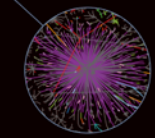
100 Million
YouTube videos downloaded every day.
(Source: YouTube)

161
Exabytes of raw electronic data created every year.
(Source: ICS)

12 Million
Miles of new fiber deployed in 2006.
(Source: Telecommunications Industry Association)

15 Million
Miles of new fiber to be deployed annually by 2009.
(Source: Telecommunications Industry Association)

\$72.5 Billion
Annual spending in support of network infrastructure in the United States by 2009.
(Source: Telecommunications Industry Association)



These large groups represent routing hubs. This particular cluster is a routing hub in South America that links scores of other routers, while usually sitting "down below" (regardless of where a specific network's engineering location is) between providers. They do not necessarily indicate the relative size of the network topology.

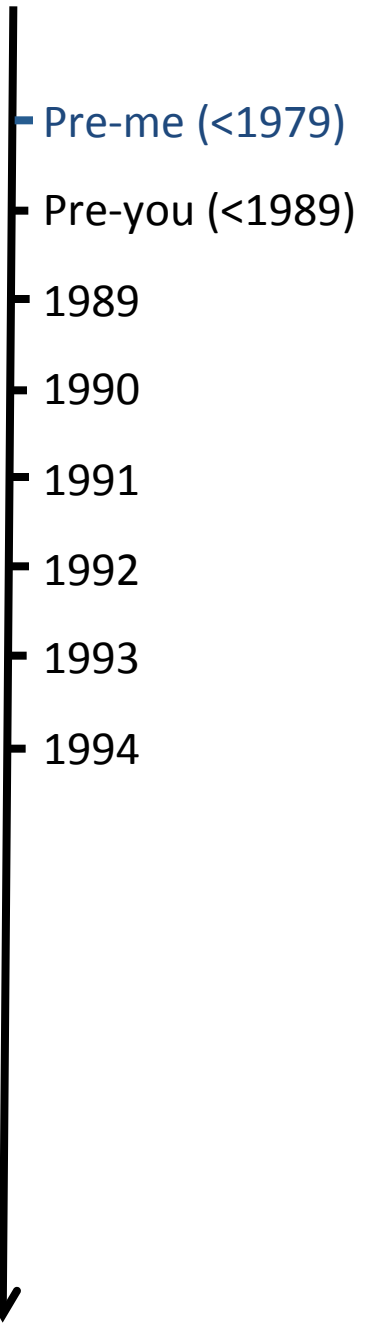


Internet 2007 (just the backbone)

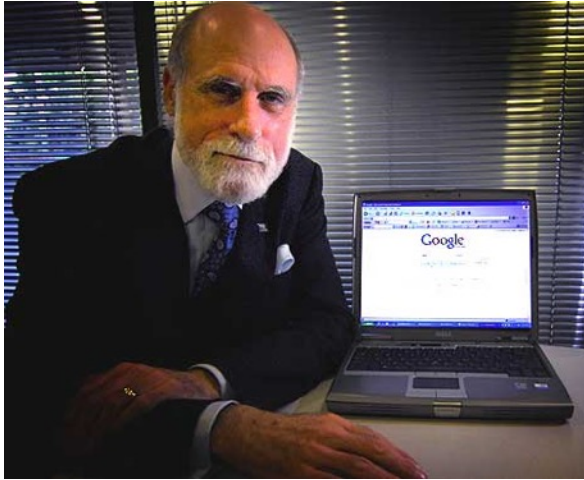
1971



Ray Tomlinson creates first email program



1974



Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

1993

1994

TCP / IP defined by Vint Cerf & Bob Kahn



2004: both received the Turing Award



1984



Paul Mockapetris introduces DNS

Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

1993

1994



1989 – The Web Emerges

Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

1993

1994



The original proposal of the WWW, HTMLized - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.w3.org/History/1989/proposal.html

Information Management: A Proposal

Tim Berners-Lee, CERN
March 1989, May 1990

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext system.

Overview

Many of the discussions of the future at CERN and the LHC era end with the question - "Yes, but how will we ever keep track of such a large project?" This proposal provides an answer to such questions. Firstly, it discusses the problem of information access at CERN. Then, it introduces the idea of linked information systems, and compares them with less flexible ways of finding information.

It then summarises my short experience with non-linear text systems known as "hypertext", describes what CERN needs from such a system, and what industry may provide. Finally, it suggests steps we should take to involve ourselves with hypertext now, so that individually and collectively we may understand what we are creating.

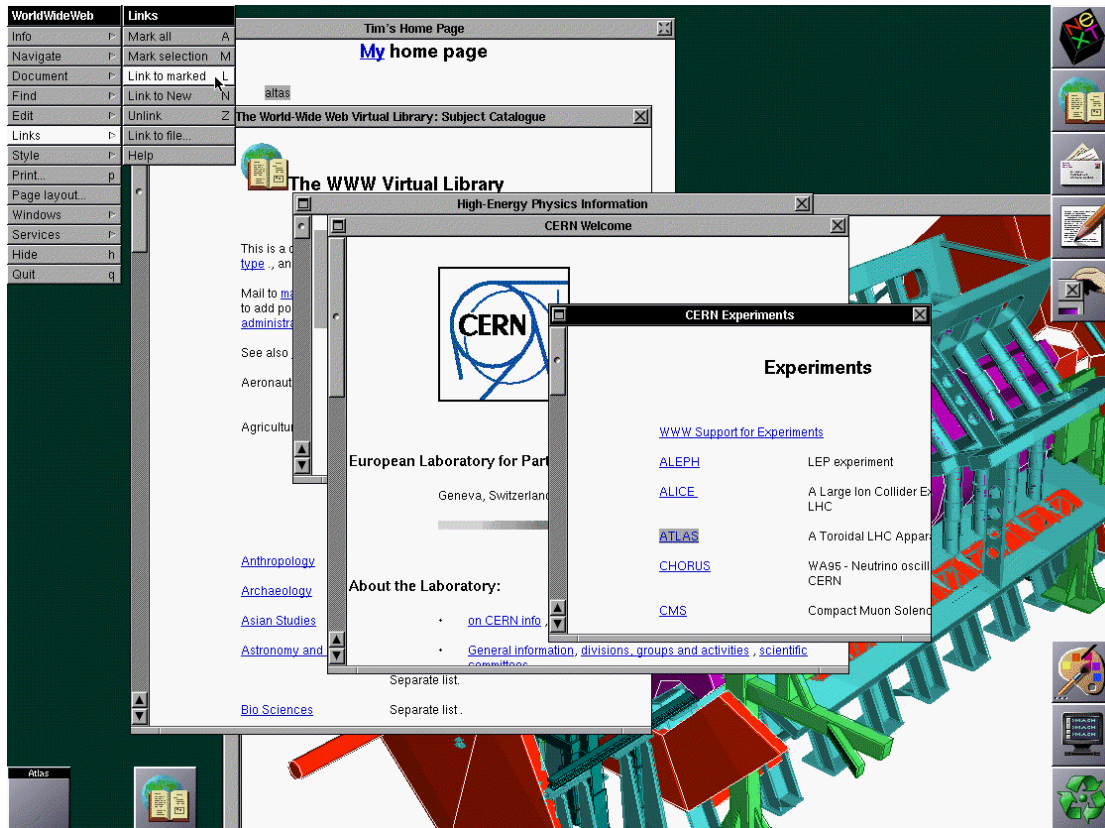
Find: broder Next Previous Highlight all Match case

Done

Tim Berners-Lee writes "Information Management: A proposal" at CERN



1990



First browser developed at CERN

Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

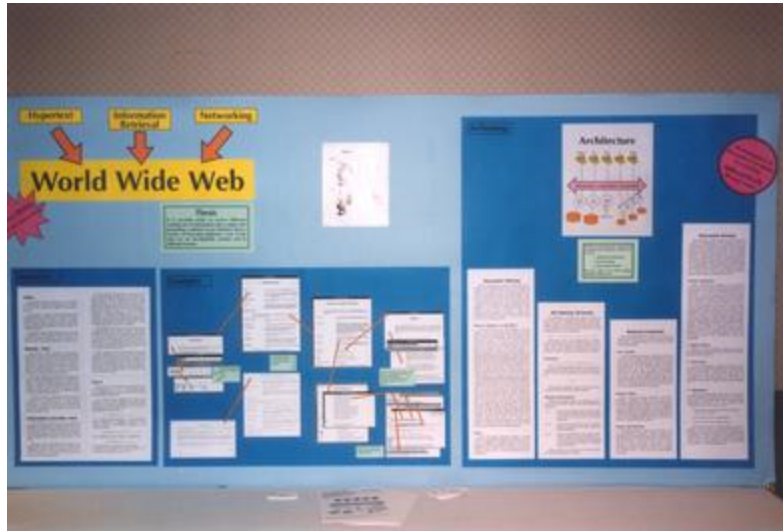
1992

1993

1994



1991



First paper appears on the project at
Hypertext conference

→ Only accepted as a poster!

Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

1993

1994



1993



Pre-me (<1979)

Pre-you (<1989)

1989

1990

1991

1992

1993

1994

Mosaic became the first graphical browser

CERN agrees to allow public use of web protocol royalty-free!



1994

- Mosaic goes commercial (later becomes Netscape)
- Traditional dialups (AOL, CompuServe, Prodigy) begin to sell Internet access.



Yahoo
circa
1996

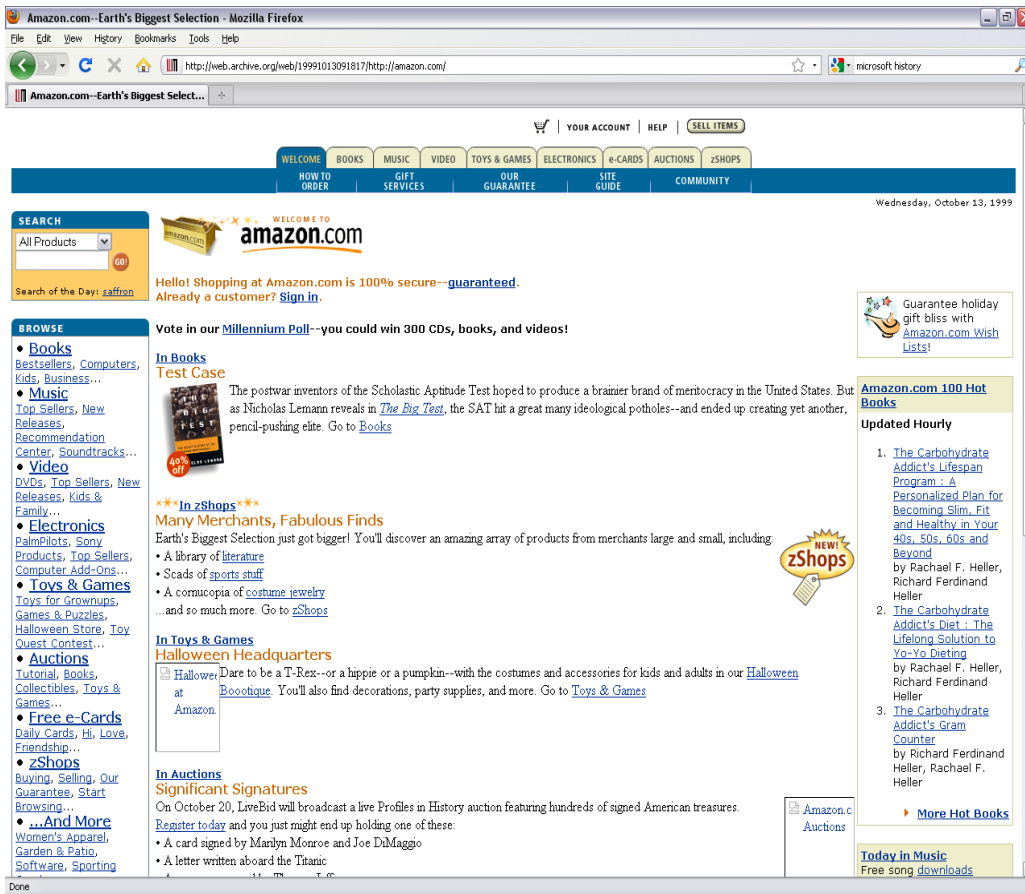
“Jerry’s Guide to the world wide web” started ...
it eventually became Yahoo

- Pre-me (<1979)
- Pre-you (<1989)
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994



1995+

Amazon arrives and the commercialization of the web begins



Amazon
circa
1999

- Pre-me (<1979)
- Pre-you (<1989)
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994



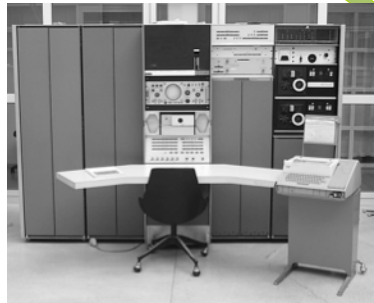
Today

- How many connected devices do you have?
- Many!
 - Desktop
 - Laptop
 - (Smart)phone
 - Tablet
 - TV / gaming console
 - ...

Summary: A bit of History

Size per device

Number of Devices

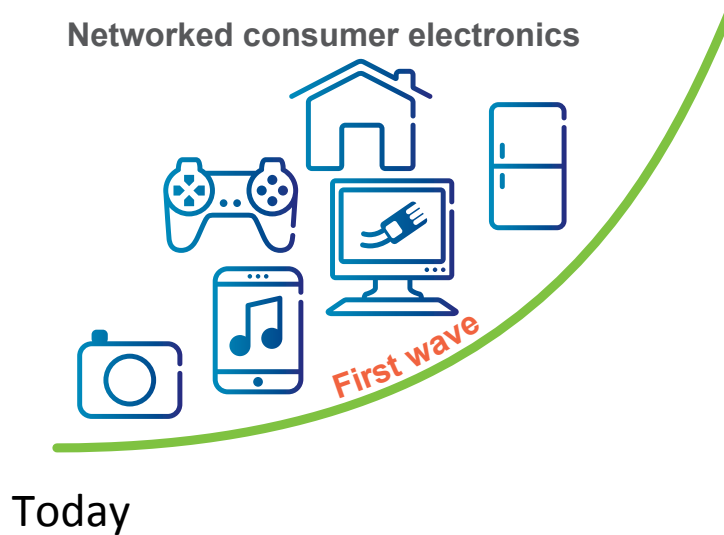


Mainframe age (60's & 70's):
One computer for many

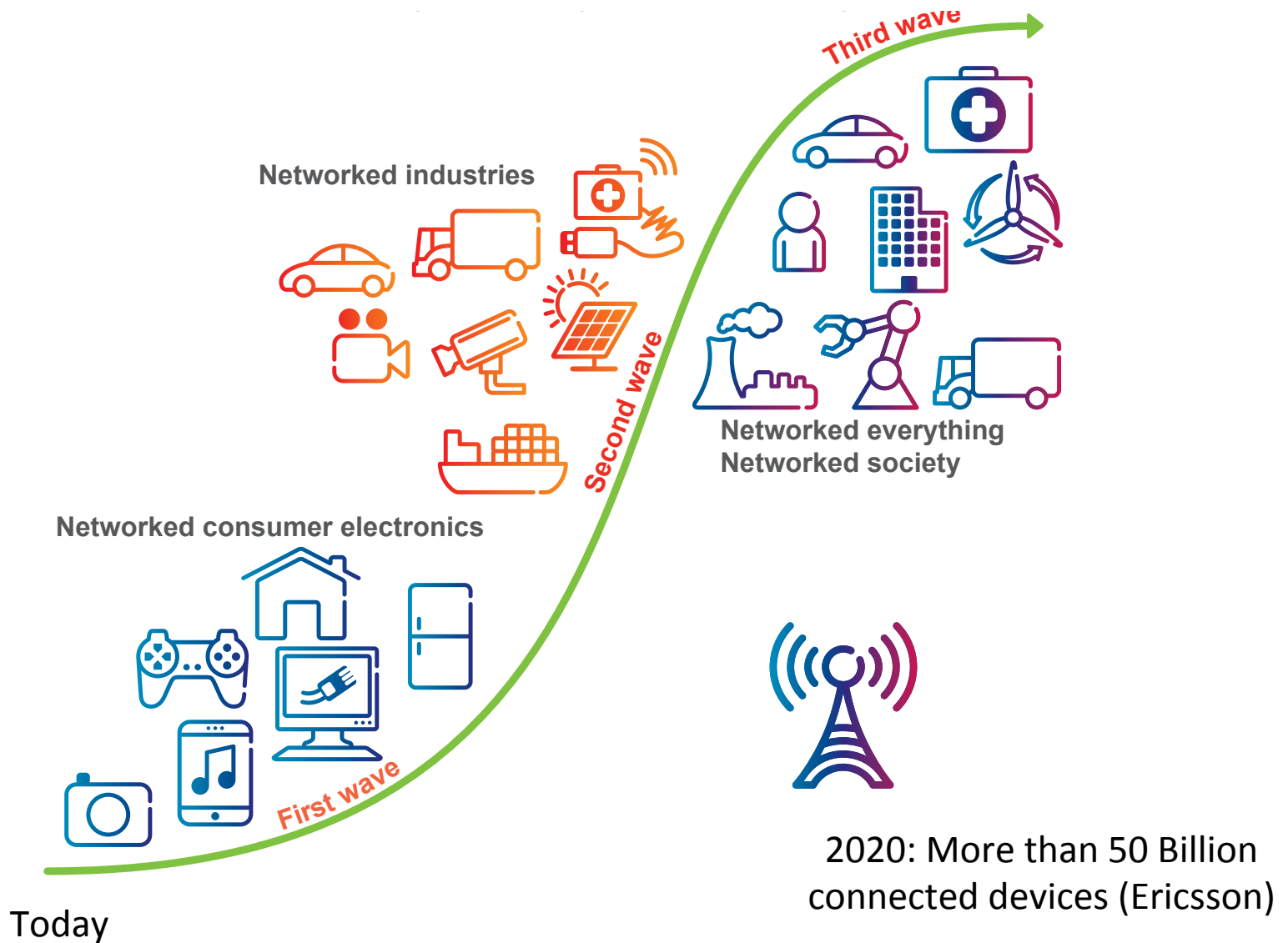
PC age (80's & 90's):
One computer for each,
partially networked

Cloud computing
Mobile, ubiquitous computing
(Today, > 2000):
Many computers for each,
networked

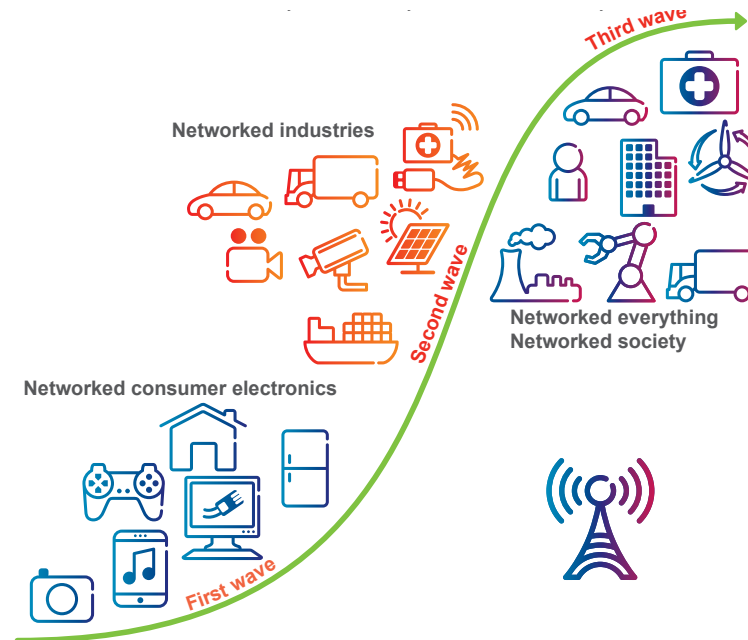
Tomorrow?



Tomorrow?



Tomorrow? Networked Society!



- Distributed Systems touch all aspects of daily life!
 - Integral building block for our networked society
 - Strongly increasing in numbers
 - Result: Very good topic to study ;-)

COURSE TOPICS

Course Topics: Motivation

- Assume: your task is to build
 - Facebook or
 - Amazon or
 - just a simple web application
- What challenges do you face?

The Eight Fallacies of Distributed Systems

- The network is reliable
- Latency is zero
- Bandwidth is infinite
- The network is secure
- Topology doesn't change
- There is one administrator
- Transport cost is zero
- The network is homogeneous

Mechanisms

- This course
 - Mechanisms to deal with these challenges
 - Generic mechanisms
 - Not bound to the Internet
 - But: Examples mostly Internet bound
 - Easier to understand for most students
 - Compared to power grids, cars, ...

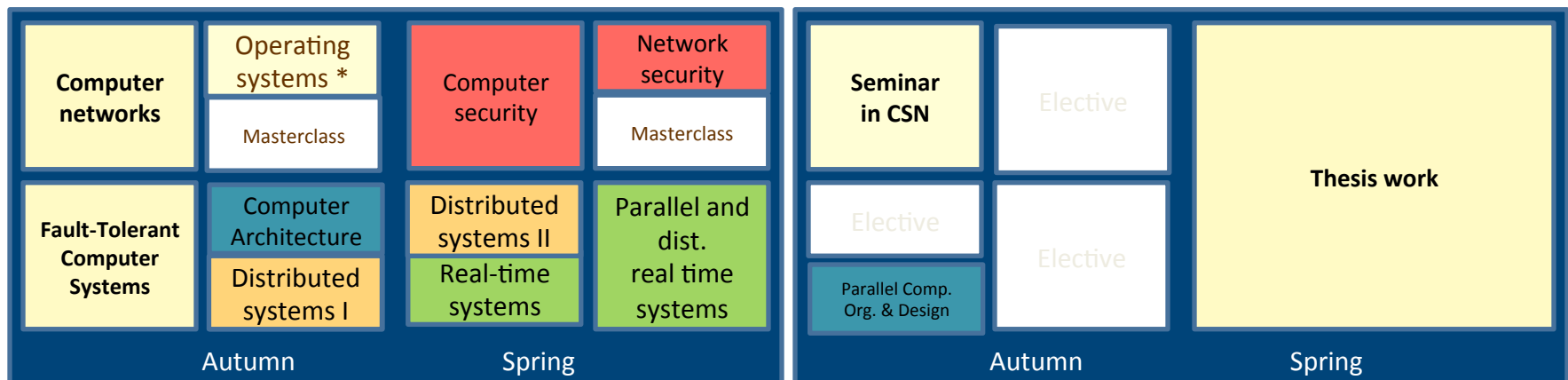
Course Content: Mechanisms

- Architectures & Processes
- Mutual exclusion & Election
- Naming
- Clocks and Time
- Consistency & replication
- Fault tolerance

Computer Systems and Networks

120 credits (MSc, 2 years)

Distributed Systems Profile



Also available as
elective courses
from other
programs

Questions