Cristina Nita-Rotaru

CS4700/5700: Network fundamentals

Introduction: Class overview. History.

1: Class overview

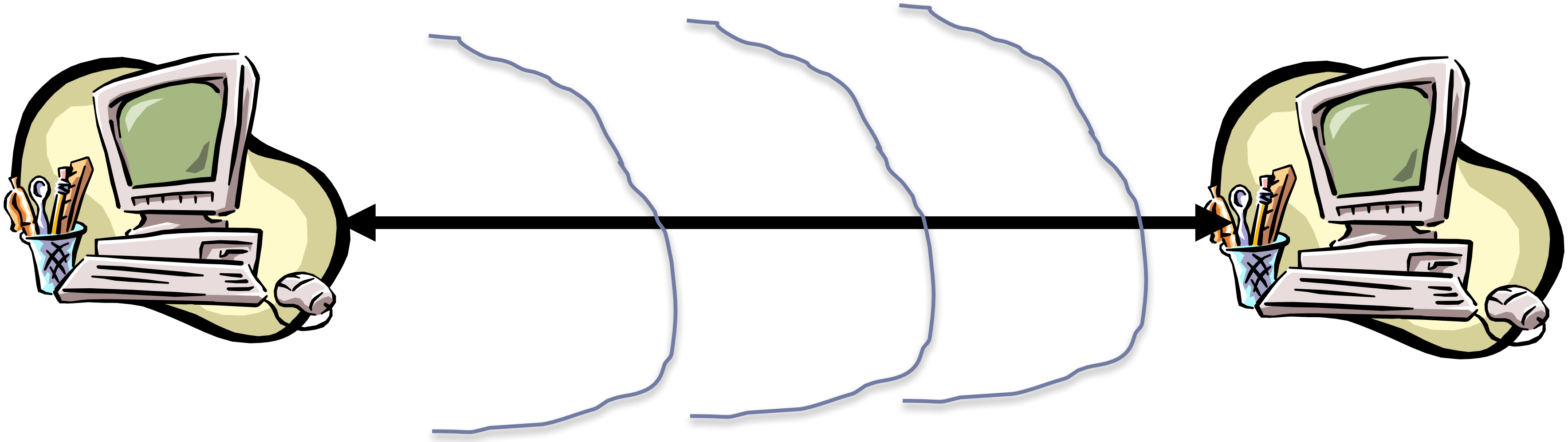
Course information

- Meetings
  - TF 9:50-11:30 Robinson 411
- Professor contact info:
  - Office: 626 ISEC
  - Email: c.nitarotaru
  - Office hours: Tu 5 - 6pm and by appointment
- Class webpage

  http://cnitarot.github.io/courses/nt_Fall_2017/index.html
- Use Piazza for questions and postings
- Hw and projects posted on piazza

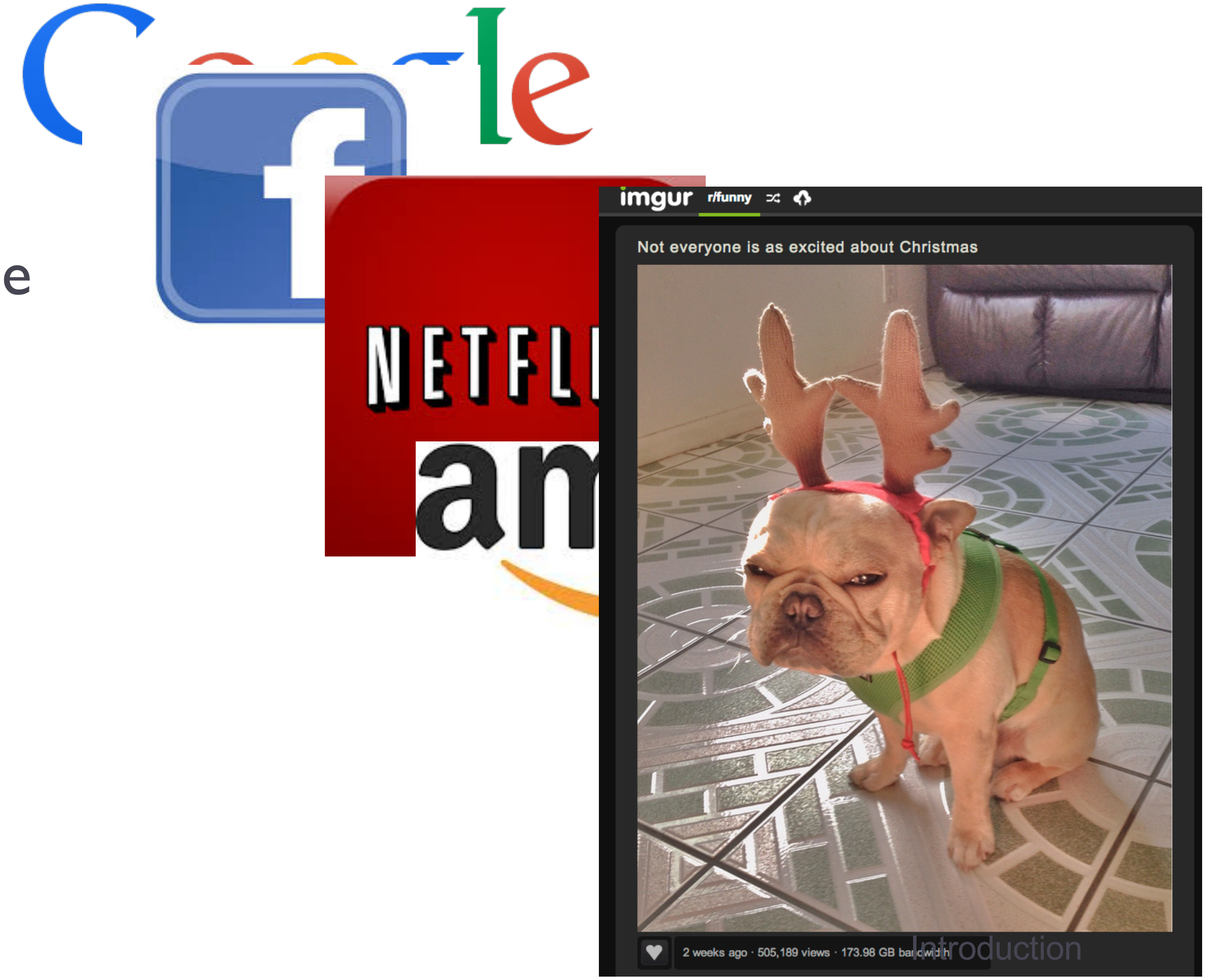
What are computer networks?

They help us communicate



Computer networks are ubiquitous

- Networks touch every part of our daily life
  - Web search
  - Social networking
  - Watching movies
  - Ordering merchandise
  - Wasting time



Not everyone is as excited about Christmas

2 weeks ago · 505,189 views · 173.98 GB bandwidth

Computer networks are ubiquitous

- Networking is one of the most critical topics in CS
  - There would be no…
    - Big Data
    - Cloud
    - Apps or Mobile Computing
    - Streaming video
    - WoW
    - Social Networks
    - VoIP
    - …
  - … without networks

Why take the class

- It’s cool to know how Internet (and computer networks work)
- Networks are fundamental to computer science
  - Anything we do today involves some form of networking
- Getting a good job
  - Manager of one of Amazon’s core services (think S3, EC2): “Can I take this class?”
  - Akamai Manager:“I think your CDN project should be required each new hire for their first 3 months”
  - Google Manager:“This is really cool.”

What is this class about

- Fundamental understanding about computer networks
  - All the way from bits on a wire…
  - … across the ever-evolving Internet…
  - … to distributed applications
- Focus on software and protocols
  - Not hardware
  - Some theory
- Project-centric, hands on experience
  - Programming APIs
  - Network simulation
  - Application-level protocols
  - Globally distributed systems

Prerequisites

- Strong systems background
  - Assembly language and memory layouts
  - Operating systems
- Fluency in many languages
  - C/C++
  - HTML and Javascript
  - Python or some other scripting language
- Linux command line proficiency
- Computer security and cryptography fundamentals

Schedule

- Tentative schedule available on the class website
- Make sure you check it for updates

- I will travel on Friday Oct. 6 and Nov. 17; somebody will replace me on those days

Grading policy

Written assignments	15%
Programming projects	40%
Midterm	20%
Final	25%

- There is no curve for grades
- Final grades are based on a simple scale:
  - A >92, A- 90-92, B+ 87-89, B 83-86, B- 80-82, …

Written assignments

- **Purpose of the written assignments is to prepare you for the midterm and final exams**
  - **Read the material before solving them and solve them with closed books and notebooks**
- 3 written theoretical assignments
- Homework is individual
- Homework must be typed – PDF submission format only
  - You can include images of photos on YOUR OWN drawings whiteboard, paper, etc as long as they are clear; do not include pictures from books or Internet
- For submission, follow the information in the homework description

Programming projects

- **Purpose of the programming projects is to help you understand practical aspects of things discussed in class**
  - **Read all material in class and the description of the project in details before starting**
  - **Make sure you understand the observed results for the items you are asked to investigate for the reports**
- 3 programming projects
- Programming projects are individual
- All the code must be from scratch
- Use the VMs/machines specified in the project description

Late policy

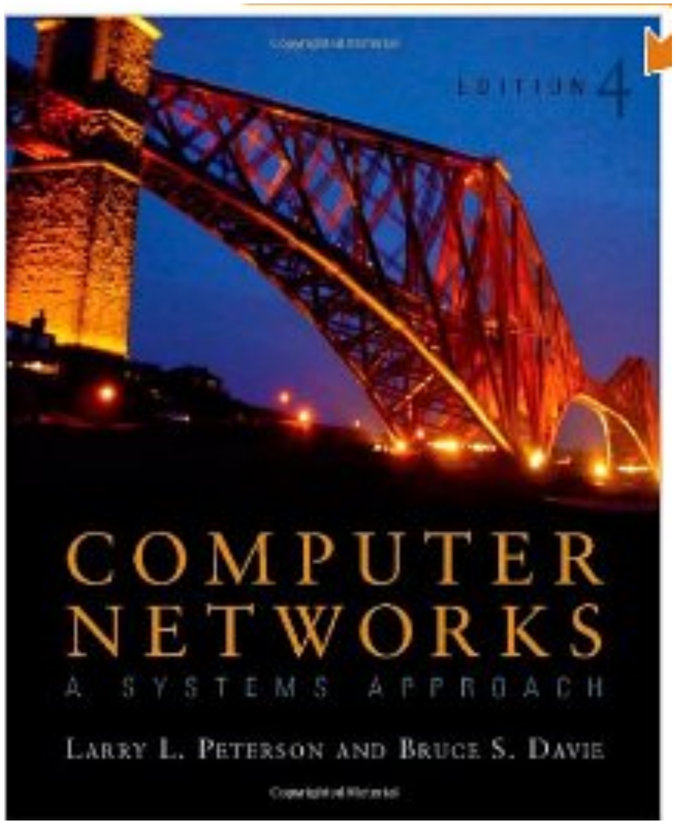
- Each of you gets 5 LATE DAYS that can be used any way you want for homework and projects; you do not need to let us know if you plan to take any late day; just submit late
  - Keep track of your late days used
  - 20% off from grade obtained per day late
- Do not wait till the last moment
- Follow the requirements from project description to see how to submit
- **Assignments are due at 9:59:59 pm, no exceptions**
  - **1 second late = 1 hour late = 1 day late**

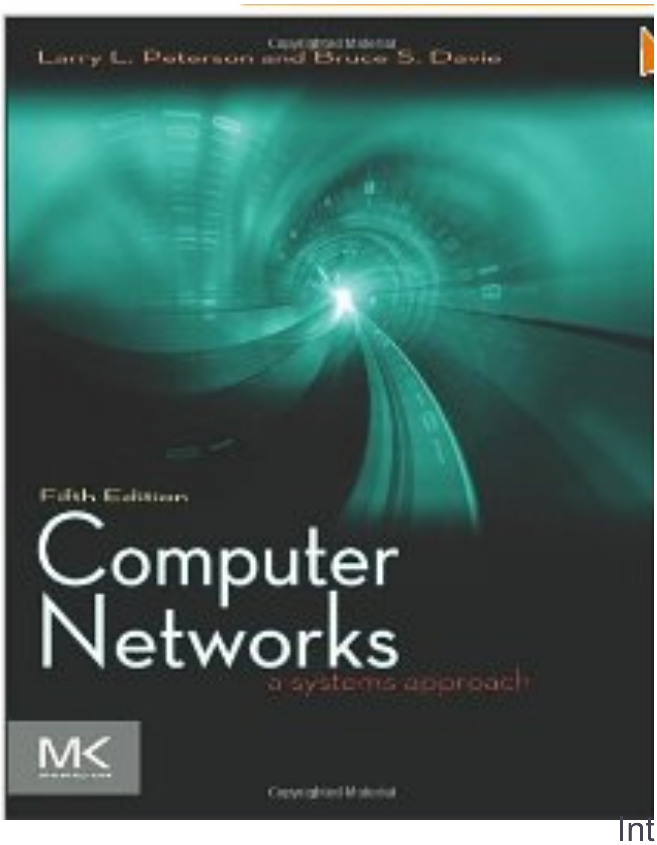
Midterm and final exams

- Midterm is in class: Oct. 24 in class
- Final is in class: Dec. 4
- We will have review for the midterm and final
- We will discuss the midterm solutions in class
- All exams are closed books, closed notebooks
- No electronic devices, laptops, tablets, phones, etc
- Exams cover everything, including written assignments and projects
- THERE ARE NO MAKEUP EXAMS

Textbook

- Computer Networks: A Systems Approach
  - Peterson and Davie
  - 5th Edition





Class attendance and notes

- Your are strongly recommended to attend and take notes
- If you miss class is your responsibility to go through the covered material on your own
- Slides will be made available online before lecture;
- There will be assigned reading from papers and other online materials
- Be active on Piazza
- Ask questions in class
- Answer questions in class

Regrading

- YOU HAVE 1 WEEK to ASK for REGRADING of a homework, project or midterm from the moment solutions were posted on piazza or discussed in class
- Make sure you read and understand the solution before asking for a regrade
- Request for a regrade will result in the regrading of the entire homework, project or midterm

Academy integrity

- It is allowed to discuss homework problems before writing them down; however, WRITING IS INDIVIDUAL
  - if you look at another student's written or typed answers, or let another student look at your written or typed answers, that is considered cheating.
- Never have a copy of someone else's homework or program in your possession and never give your homework (or password) or program to someone else.
- NO CHEATHING WILL BE TOLERATED.
- ANY CHEATING WILL AUTOMATICALLY RESULT in F grade and report to the university administration

How to ask on Piazza

- Read slides, notes, homework or project description
- Use #hashtags (#lecture2, #project3, #hw1, etc.)
- Describe the problem clearly, using the right terms
- Add code in attached files
- Add output from compiler
- Add any other relevant information
- **Don’t post solutions on piazza**
- **Anything that relates to solution post PRIVATELY**

Weather/Emergency

- In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control.
- Monitor weather and piazza particularly if you don't live close to school.

PIAZZA ACCOUNTS

- All communication is on piazza, make sure you get notifications and you check piazza constantly
- If you have not received a piazza notification email me c.nitarotaru@neu.edu

One last word …

- **No meetings will be accepted with the TA or instructor the day homework or projects are due, or the day of exam**
- Start early, plan carefully
- Develop your solution gradually, test gradually so you always have functionality for which you can receive a grade; YOUR CODE MUST WORK
- Do not wait to submit your code last minute
- Don’t post solutions on piazza
- Don’t cheat

2: A trip down the history lane

What is a **communication network**?

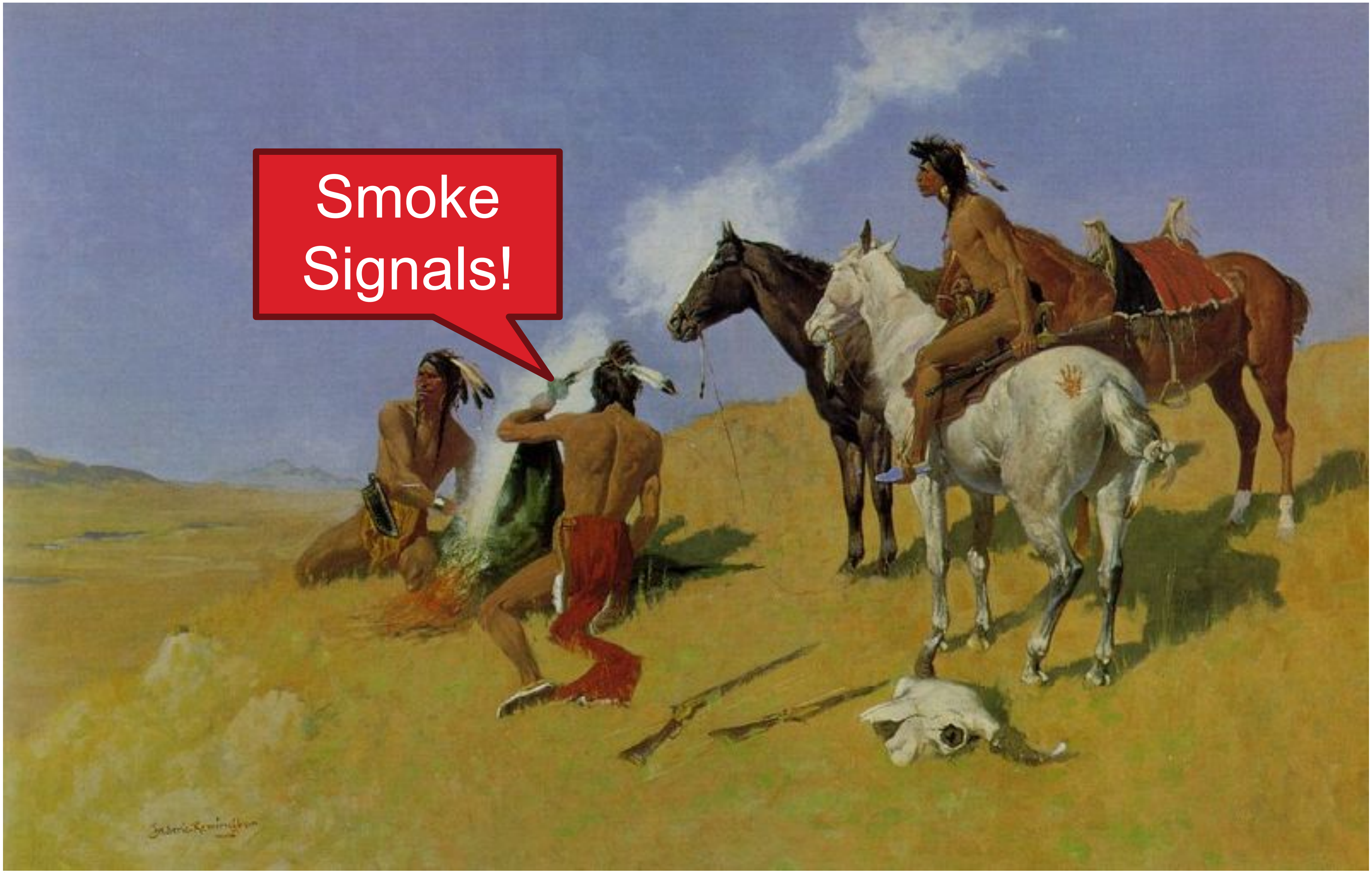
A communications network is a network of links and nodes arranged so that messages may be passed from one part of the network to another

- What a
  - Peopl
  - Teleph
  - Comp
- What i
  - **Information**

Networks are key for:

- Speed
- Distance

Networks are fundamental



Smoke Signals!

Networks are old

- 2400 BC: courier networks in Egypt
- 550 BC: postal service invented in Persia

Problems:

- Speed
- Reliability
- Security

Towards electric communication

- 1837: Telegraph invented by Samuel Morse
  - Distance: 10 miles
  - Speed: 10 words per minute
  - In use until 1985!
- Key challenge: how to encode i
  - Originally used unary encoding

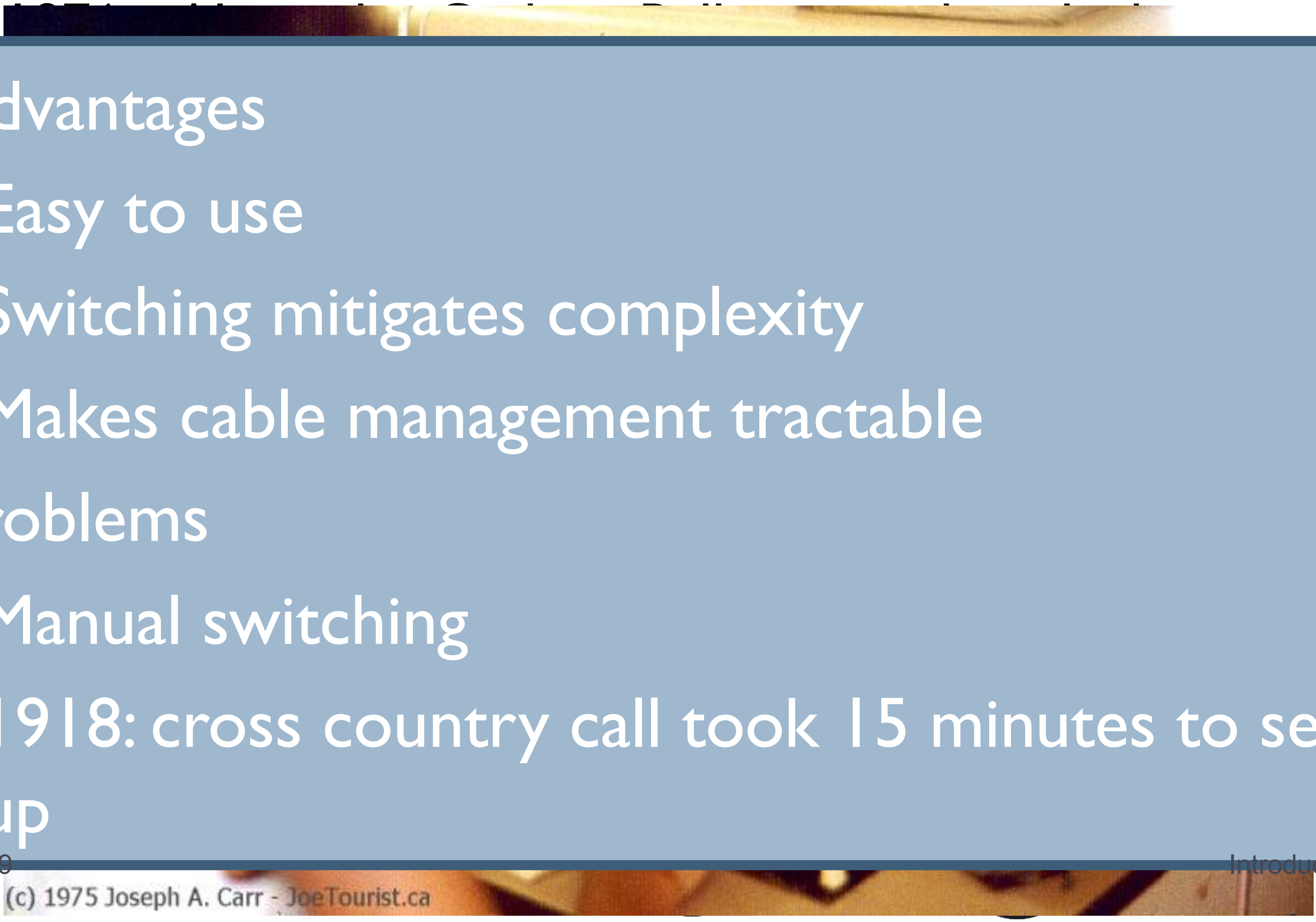
    A • B •• C ••• D •••• E •••••

  - Next generation: binary encoding

    A •— B —••• C —•—• D —•• E •

Higher compression = faster speeds

Telephony



(c) 1975 Joseph A. Carr - JoeTourist.ca

Advantages

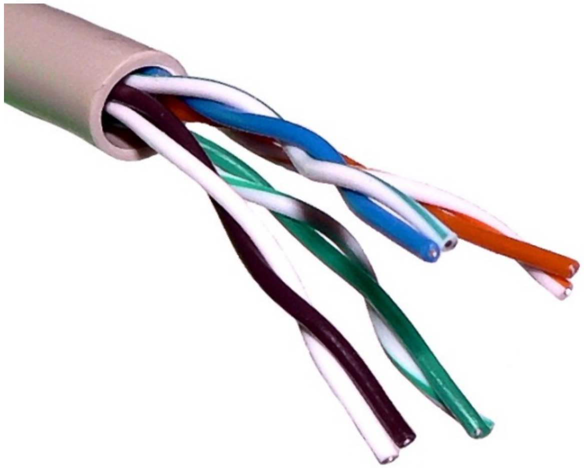
- Easy to use
- Switching mitigates complexity
- Makes cable management tractable

Problems

- Manual switching
- 1918: cross country call took 15 minutes to set up

Growth of the telephone network

- 1881: Twisted pair for local loops
- 1885: AT&T formed
- 1892: Automatic telephone switches
- 1903: 3 million telephones in the US
- 1915: First transcontinental cable
- 1927: First transatlantic cable
- 1937: first round-the-world call
- 1946: National numbering plan

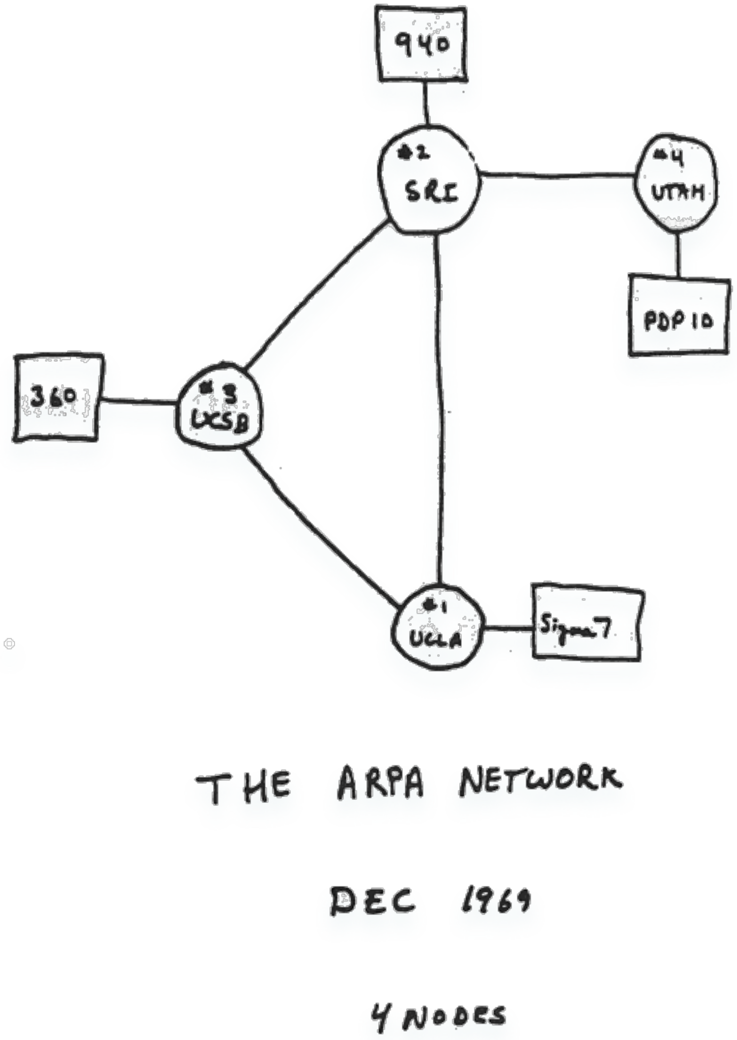


at&t

Evolution of switching

- Telephone networks are **circuit switched**
  - Each call reserves resources end-to-end
  - Provides excellent quality of service
- Problems
  - Resource intense (what if the circuit is idle?)
  - Complex network components (per circuit state, security)
- **Packet switching**
  - No connection state, network is store-and-forward
  - Minimal network assumptions
  - Statistical multiplexing gives high overall utilization

The world's most successful computer science research project



THE ARPA NETWORK

DEC 1969

4 NODES

FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)

History of the Internet

- 1961: Kleinrock @ MIT: packet-switched network
- 1962: Licklider' s vision of Galactic Network
- 1965: Roberts connects computers over phone line
- 1967: Roberts publishes vision of ARPANET
- 1969: BBN installs first InterfaceMsgProcessor at UCLA
- 1970: Network Control Protocol (NCP)
- 1972: Public demonstration of ARPANET
- 1972: Kahn @ DARPA advocates Open Architecture
- 1972: Vint Cerf @ Stanford writes TCP

1969: First message on the Internet

- https://www.youtube.com/watch?v=khajeqHUQ7Q

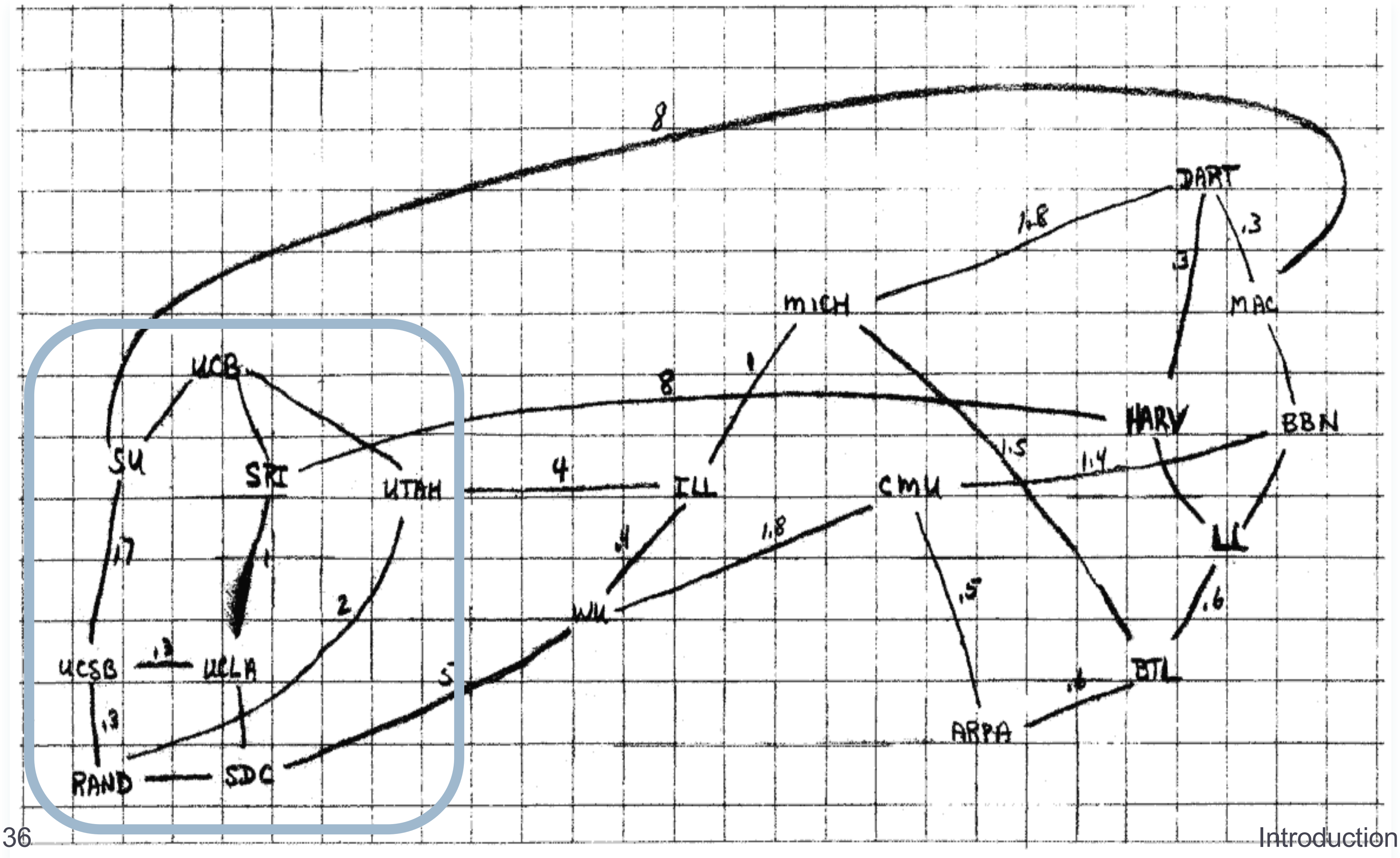
From humans to computers

- 19

- M

ched

The 1960s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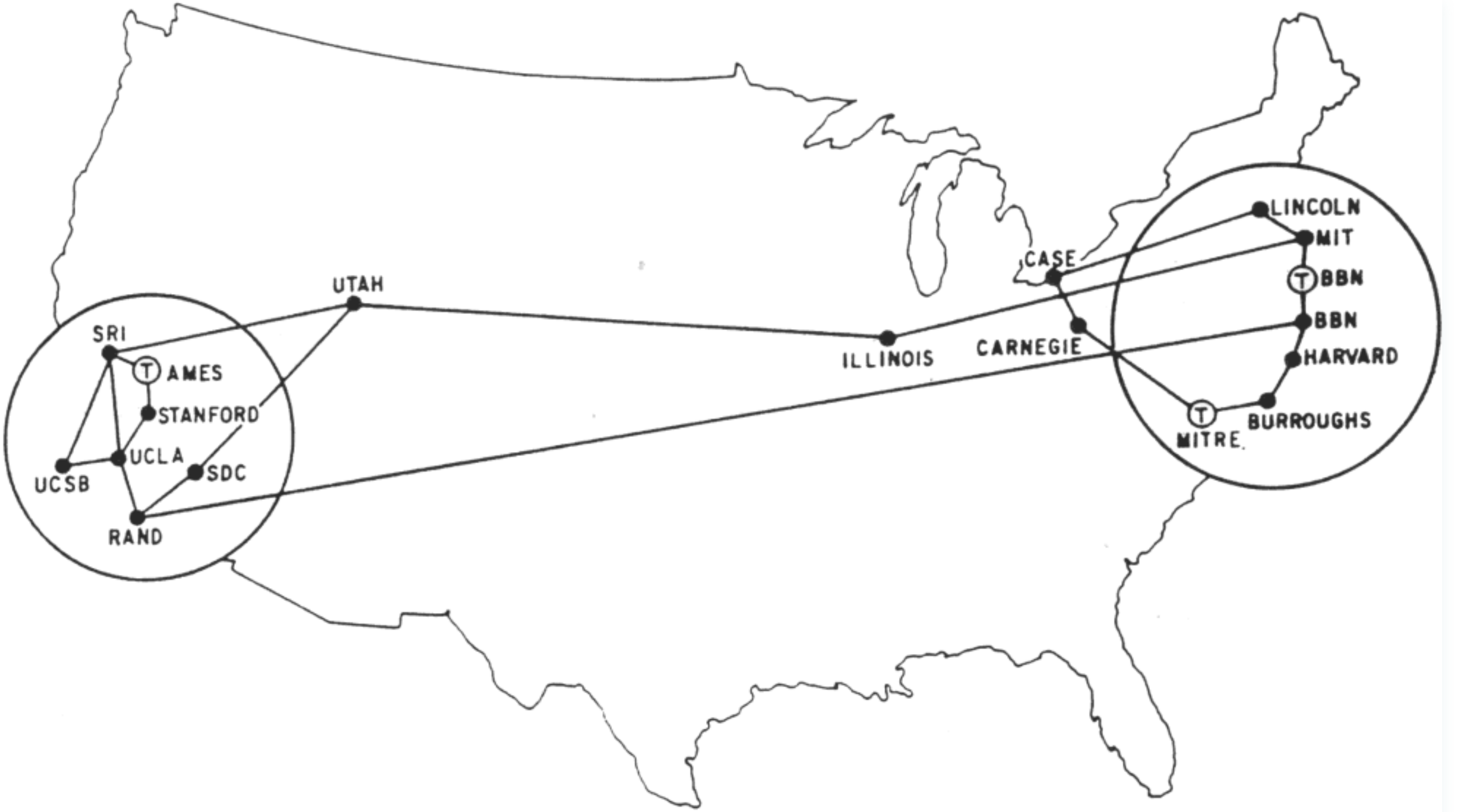
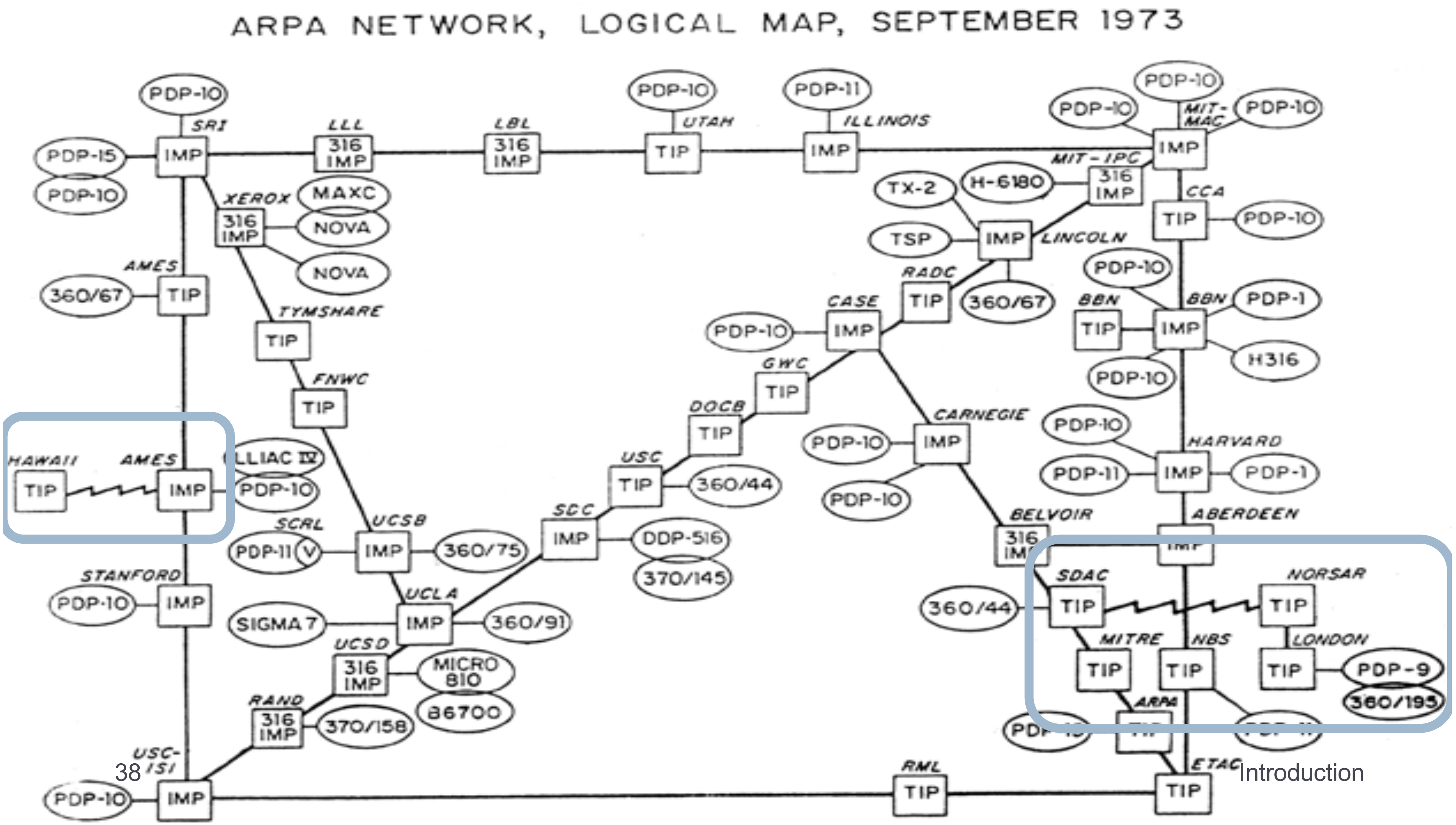


MAP 4 September 1971

1973



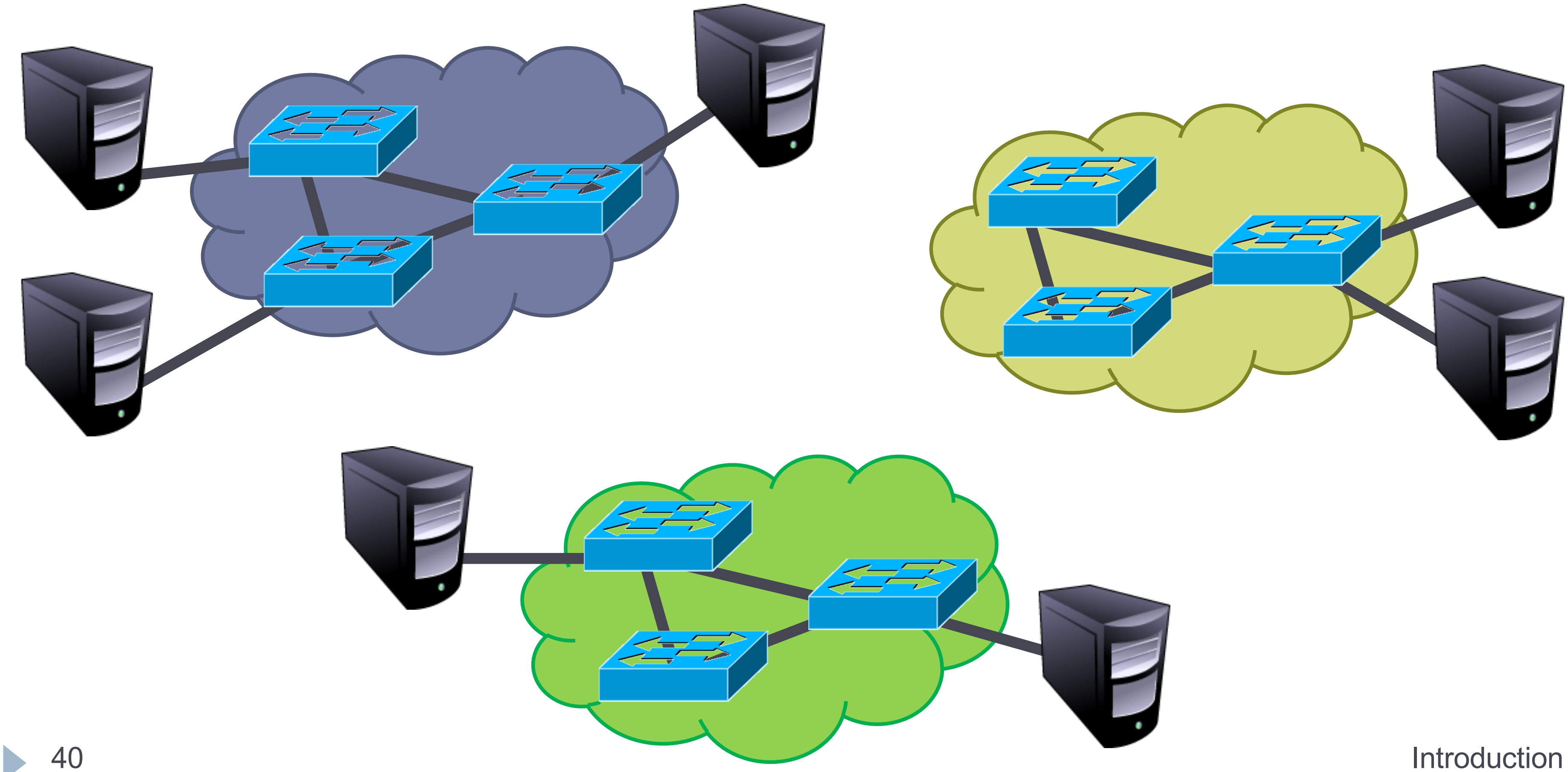
ARPA NETWORK, LOGICAL MAP, SEPTEMBER 1973

1973: How was TCP created

- https://www.youtube.com/watch?v=gZINNiI-hq0

Growing pains

- Problem: early networks used incompatible protocols

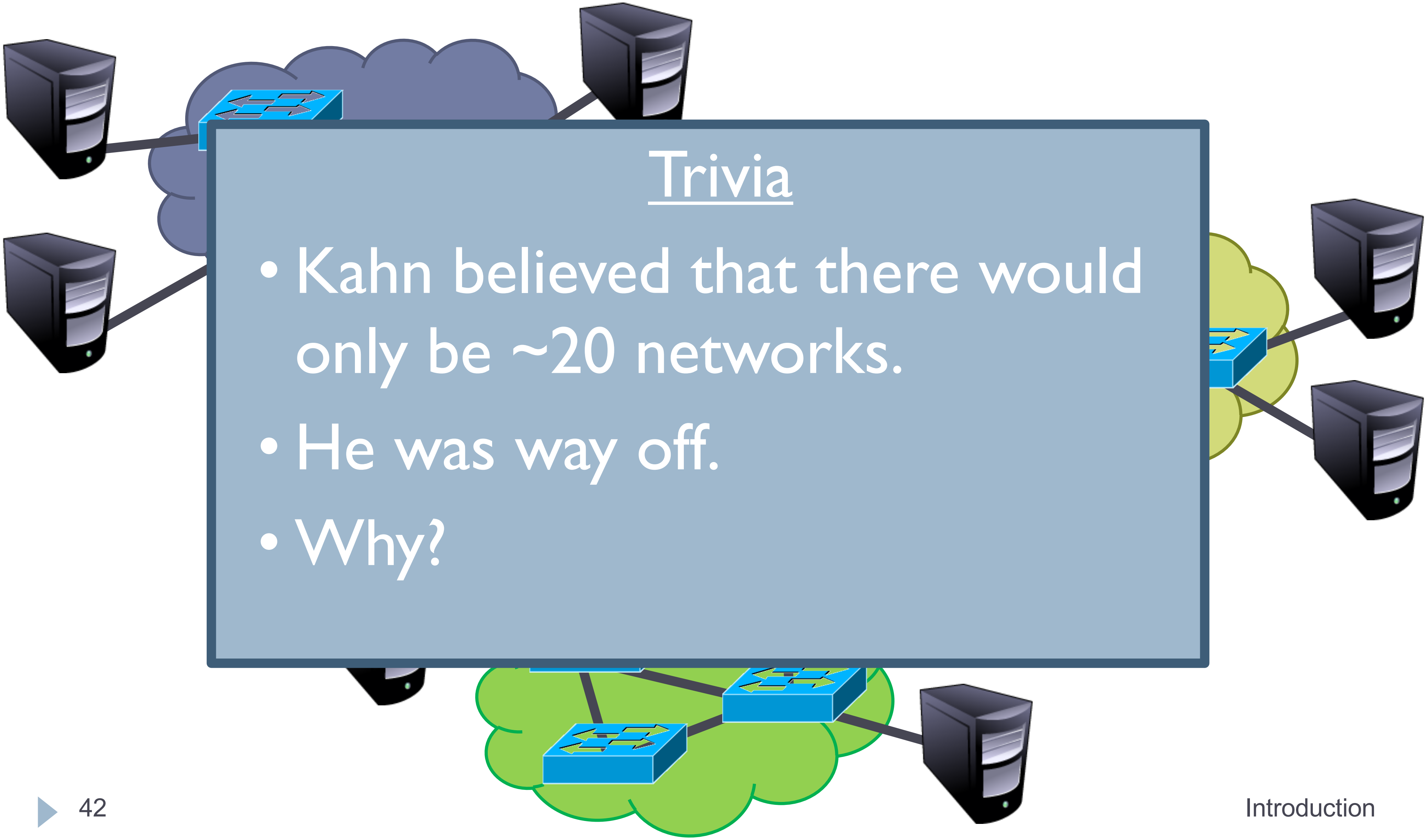


Kahn's ground rules

1. Each network is independent, cannot be forced to change
2. Best-effort communication (i.e. no guarantees)
3. Routers connect networks
4. No global control

- Principles behind the development of IP
- Led to the Internet as we know it
- Internet is still structured as independent networks

The birth of routing



Trivia

- Kahn believed that there would only be ~20 networks.
- He was way off.
- Why?

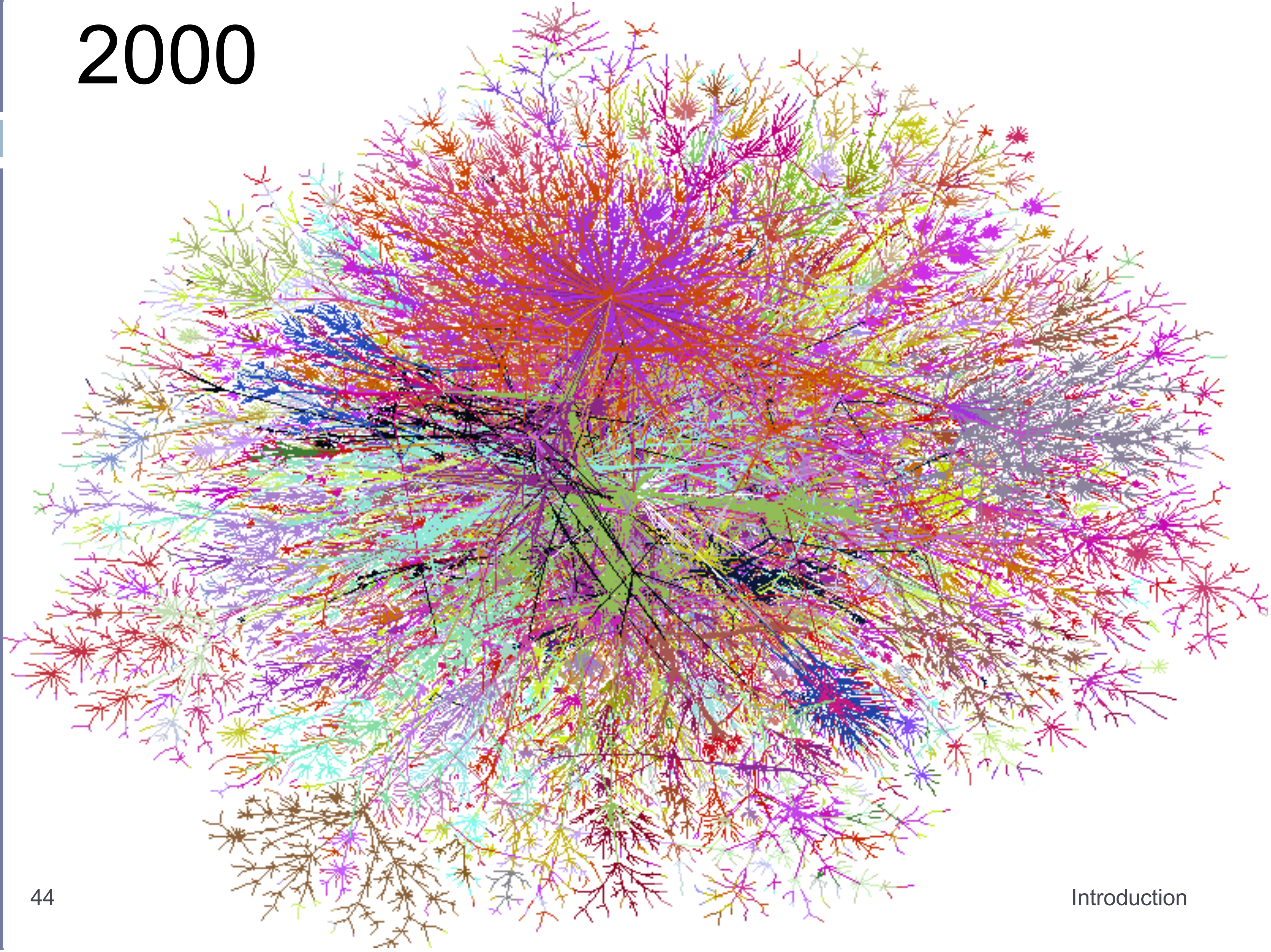
Internet applications evalution

- 1972: Email
- 1973: Telnet – remote access to computing
- 1982: DNS – “phonebook” of the Internet
- 1985: FTP – remote file access
- 1989: NFS – remote file systems
- 1991: The World Wide Web (WWW) goes public
- 1995: SSH – secure remote shell access
- 1995-1997: Insta
- 1998: Google
- 1999: Napster, b
- 2001: Bittorrent
- 2004: Facebook
- 2005: YouTube
- 2006: Twitter
- 2007: The iPhone
- 2016+: IoT, Oculus Rift, …?

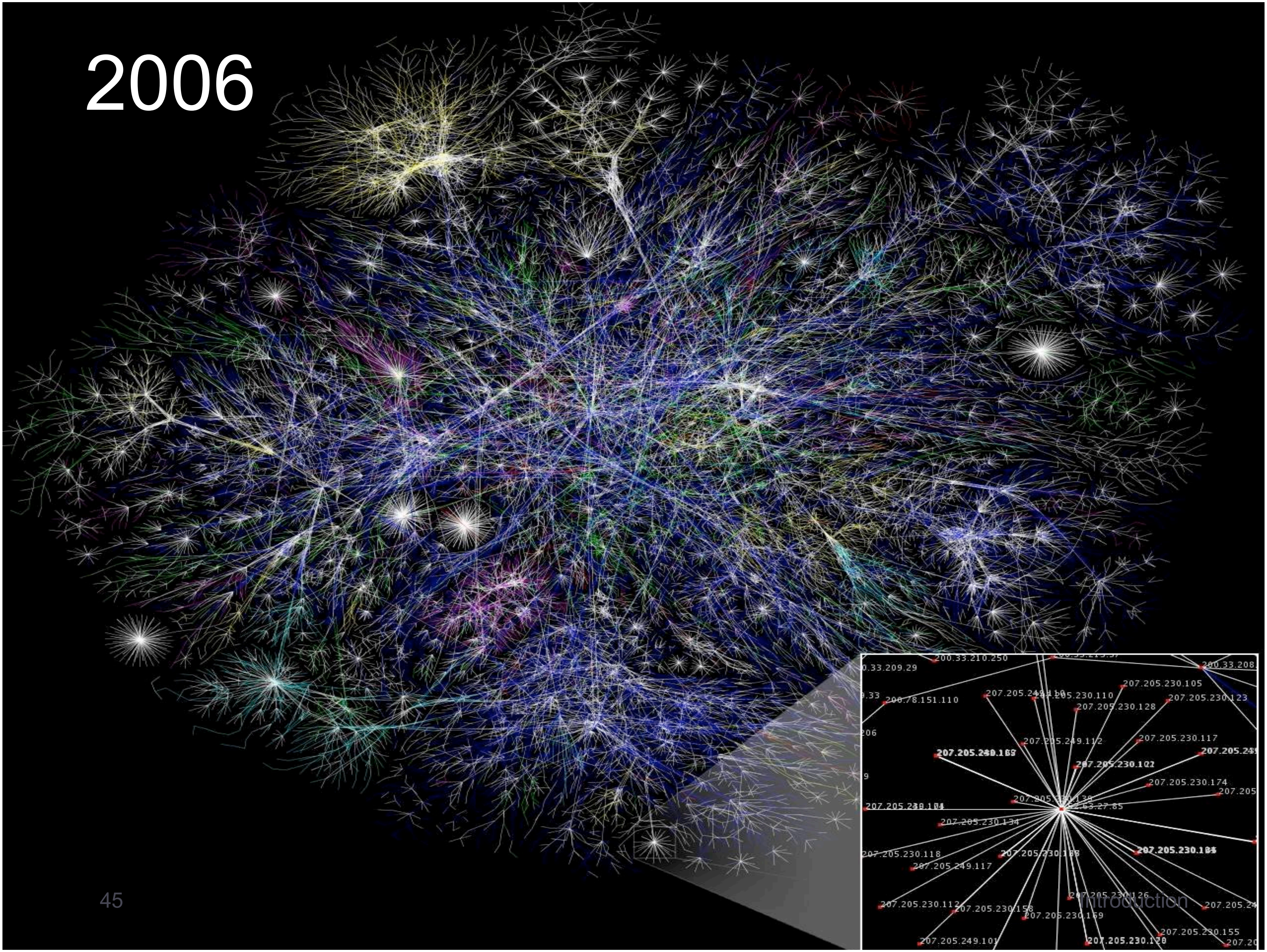
What is next?

Invented by Shawn Fanning at NEU

2000



2006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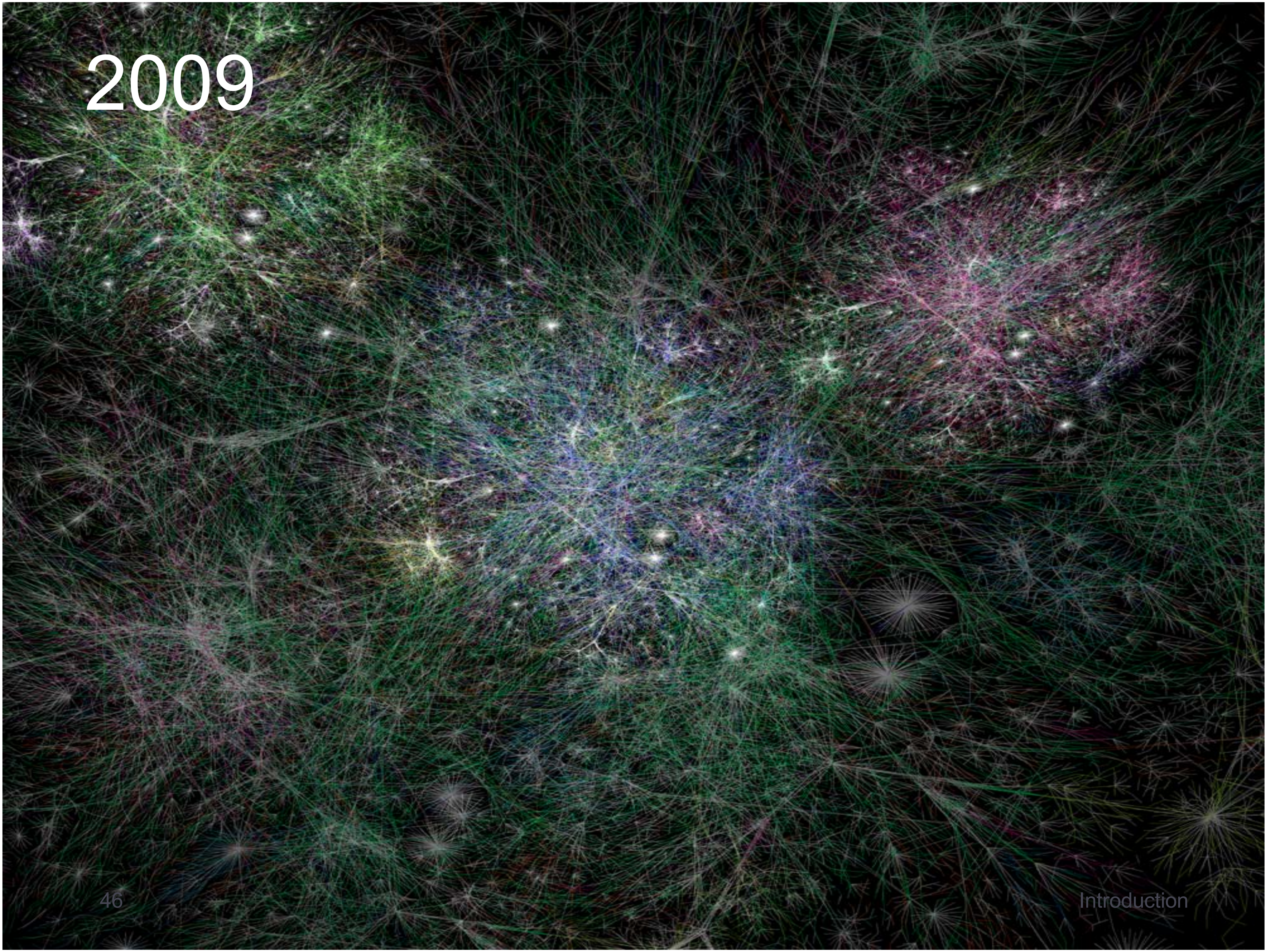
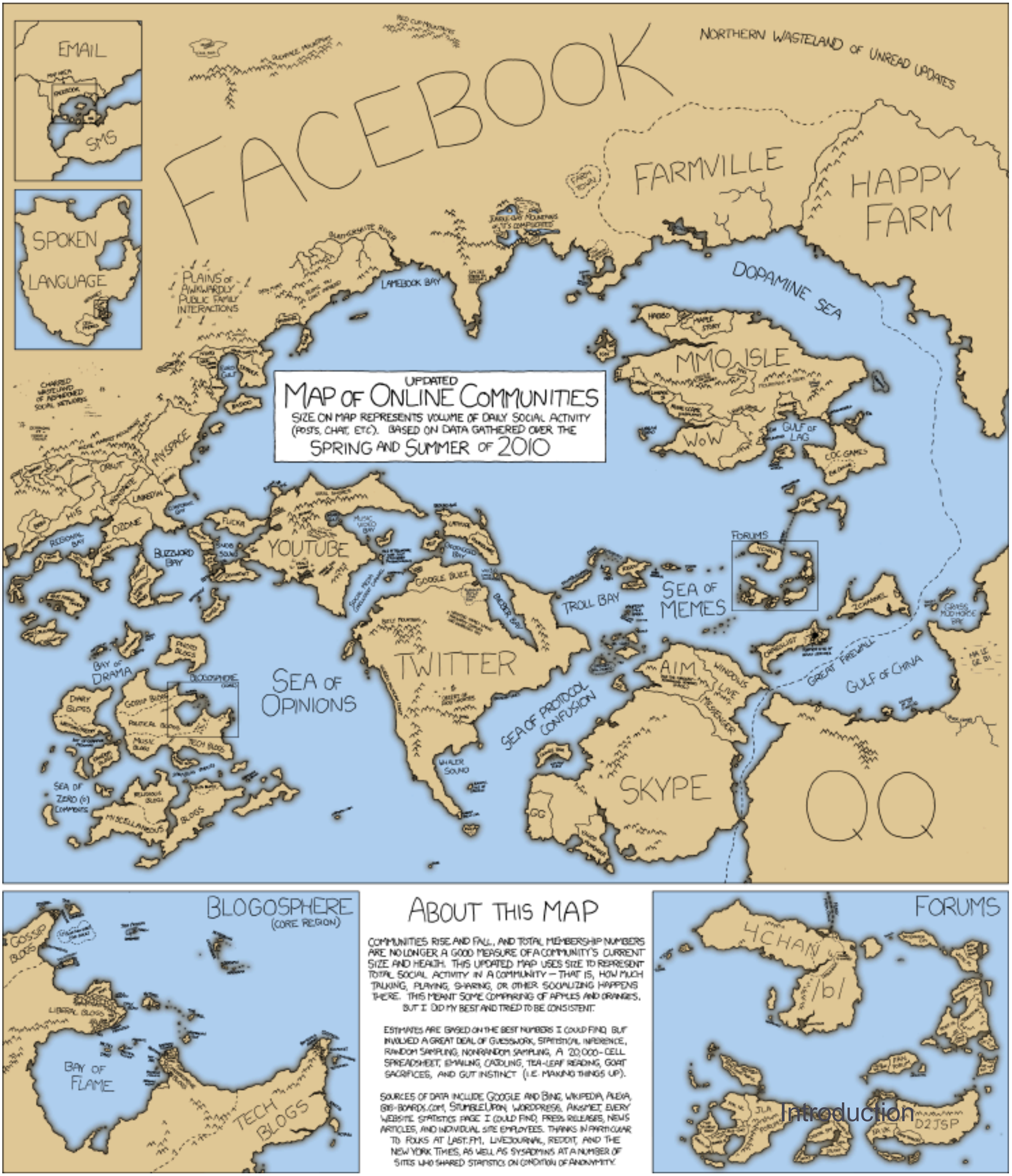


2009

2010



UPDATED
MAP OF ONLINE COMMUNITIES

SIZE ON MAP REPRESENTS VOLUME OF DAILY SOCIAL ACTIVITY (POSTS, CHAT, ETC). BASED ON DATA GATHERED OVER THE

SPRING AND SUMMER OF 2010

ABOUT THIS MAP

COMMUNITIES RISE AND FALL, AND TOTAL MEMBERSHIP NUMBERS ARE NO LONGER A GOOD MEASURE OF A COMMUNITY'S CURRENT SIZE AND HEALTH. THIS UPDATED MAP USES SIZE TO REPRESENT TOTAL SOCIAL ACTIVITY IN A COMMUNITY — THAT IS, HOW MUCH TALKING, PLAYING, SHARING, OR OTHER SOCIALIZING HAPPENS THERE. THIS MEANT SOME COMPARING OF APPLES AND ORANGES, BUT I DID MY BEST AND TRIED TO BE CONSISTENT.

ESTIMATES ARE BASED ON THE BEST NUMBERS I COULD FIND, BUT INVOLVED A GREAT DEAL OF GUESSWORK, STATISTICAL INFERENCE, RANDOM SAMPLING, NONRANDOM SAMPLING, A 20,000-CELL SPREADSHEET, EMAILING, CAJOLING, TEA-LEAF READING, GOAT SACRIFICES, AND GUT INSTINCT (I.E. MAKING THINGS UP).

SOURCES OF DATA INCLUDE GOOGLE AND BING, WIKIPEDIA, ALEXA, BIG-BOARDS.COM, STUMBLEUPON, WORDPRESS, AKISMET, EVERY WEBSITE STATISTICS PAGE I COULD FIND, PRESS RELEASES, NEWS ARTICLES, AND INDIVIDUAL SITE EMPLOYEES. THANKS IN PARTICULAR TO FOLKS AT LAST.FM, LIVEJOURNAL, REDDIT, AND THE NEW YORK TIMES, AS WELL AS SYSADMINS AT A NUMBER OF SITES WHO SHARED STATISTICS ON CONDITION OF ANONYMITY.

More Internet history

- 1974: Cerf and Kahn paper on TCP (IP kept separate)
- 1980: TCP/IP adopted as defense standard
- 1983: ARPANET and MILNET split
- 1983: Global NCP to TCP/IP flag day
- 198x: Internet melts down due to congestion
- 1986: Van Jacobson saves the Internet (BSD TCP)
- 1987: NSFNET merges with other networks
- 1988: Deering and Cheriton propose multicast
- 199x: QoS rises and falls, ATM rises and falls
- 1994: NSF backbone dismantled, private backbone
- 1999-present: The Internet boom and bust … and boom
- 2007: Release of iPhone, rise of Mobile Internet
- 201x-present: Rise of software-defined networks, smart homes

Takeaways

- Communication is fundamental to human nature
- Key concepts have existed for a long time
  - Speed/bandwidth
  - Latency
  - Switching
  - Packets vs. circuits
  - Encoding
  - Cable management
  - Multiplexing
  - Routing

- The Internet has changed the world
  - Promise of free ($) and free (freedom) communication
  - Shrunk the world
- What made the Internet so successful? Stay tuned!

What’s next

- The principles on which it was founded
- The fundamental protocols that drive it
- The various applications built atop it
- How these networks are deployed today
- Future directions it might go