Course overview

Goals

1. Introduce the basic mathematical tools to understand the fundamentals of complex networks
2. Provide the skills that are needed to perform basic analyses of such networks

Means

1. Study fundamental concepts from graph theory and random networks
2. Lots of exercises in proving properties of various well-known networks
3. Practice the use of network analysis tools: Mathematica
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Some practical matters

- In principle: per week two lectures along with one practice session and Q/A hour
  - Rena Bakhshi: Chief cook and bottle washer
  - Maarten van Steen: lectures
  - Roy, Florian, Unmesh, Vaishali, Jacco: teaching assistants

- Homework assignments:
  - Using Mathematica 9
  - Analyzing graphs

- Mandatory exercises

- There will be a midterm exam

- Exam will cover theory and homework

All material (book, slides, handouts) is online

www.distributed-systems.net
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Introduction

Evaluation last year

General remarks

Tough, not easy, lots of work, but rewarding.
# Topics covered

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What are these networks?

**Observation**

Many real-world **systems** can be viewed as a collection of **nodes** that are **linked** to each other.

1. Traffic infrastructure: roads, railways, shipping, airlines
2. Social communities: family ties, online communities
3. Communication networks: Internet, telecommunication

**Question**

What are the nodes and what are the links?
Observation

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Question

What are the nodes and what are the links?
The connected world

Observation

When it comes to connecting people, there is a long history of networks.

- In the very old days: carriers of messages (pigeons, ponies, etc.)
- Also in the old days: fire beacons, mirrors, drums, flags. Note: we need encoding schemes to use this type of communication.
- Since the late 1900s: communication networks
**Basic idea:** Set up pairs of *shutter stations*, with pairs in line of sight. Then, code the letters to be transmitted:

- **B**
  - Top row: [ ] [ ]
  - Middle row: [ ] [ ]
  - Bottom row: [ ] [ ]

- **P**
  - Top row: [ ] [ ]
  - Middle row: [ ] [ ]
  - Bottom row: [ ] [ ]

- **N**
  - Top row: [ ] [ ]
  - Middle row: [ ] [ ]
  - Bottom row: [ ] [ ]

- **E**
  - Top row: [ ] [ ]
  - Middle row: [ ] [ ]
  - Bottom row: [ ] [ ]
Electrical telegraph

Observation
By the 1850s, communication was carried over more than 30,000 kms of electrical telegraph. Shutter stations became obsolete.

Note
The world of telephony was a fact.
Telephony networks: circuits

**Observation**

In traditional telecommunications networks, to hold a conversation, it was necessary to make a **physical connection** between the two parties ⇒ **circuit-switched network**.
Observation

In modern telephony networks, everything is packetized:

- Data (including samples from continuous media) is put into a packet.
- Packets are extended with address of destination and are independently routed.
Next step

Connect many computers through switches that automatically discover and maintain routes. The Internet was born.

IMP = Interface Message Processor
The modern Internet: Some “facts”

- 2.4 billion users = 2,400,000,000
- 50 billion (indexed) Web pages = 50,000,000,000
- over 600 million Web servers
- probably over 20 million DNS servers (for resolving names)
- Over 3.5 billion Internet (IPv4) addresses: exhausted
The modern Internet on display

5 M edges
50 M routes
Red     Asia
Green   Europe++
Blue    N-America
Yellow  S-America
Cyan    CIDR addr.
White   Unknown
Network examples: Dutch railways
Network examples: Airline flights

Continental Airlines

United Airlines

Question
What main differences can be seen?
Network examples: Airline flights

Continental Airlines

United Airlines

Question

What main differences can be seen?
Network examples: social networks

Yellow: obese | Green: nonobese | Purple: friend/marriage | Red: family