

Graph Theory and Complex Networks: An Introduction

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Chapter 01: Introduction

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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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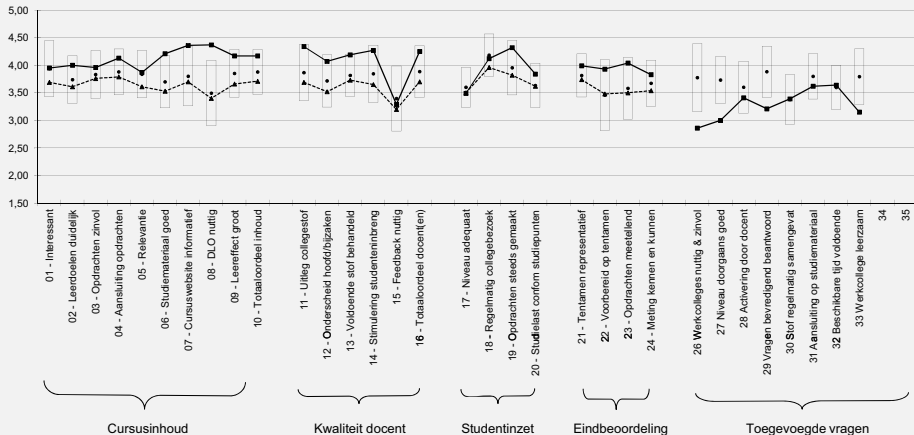
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Evaluation last year



General remarks

Tough, not easy, lots of work, but rewarding.

Topics covered

Chapter	Description
01: Introduction	History, background
02: Foundations	Basic terminology and properties of graphs
03: Extensions	Directed & weighted graphs, colorings
04: Network traversal	Walking through graphs (cf. traveling)
05: Trees	Graphs without cycles ; routing algorithms
06: Network analysis	Basic metrics for analyzing large graphs
07: Random networks	Introduction modeling real-world networks
08: Computer networks	The Internet & WWW seen as a huge graph
09: Social networks	Communities seen as graphs

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?

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The connected world

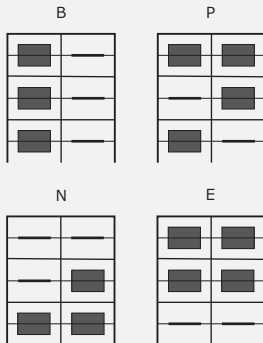
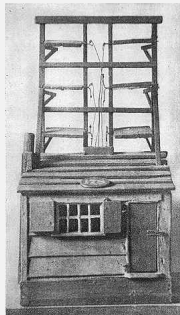
Observation

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](#)

Historical communication networks

Basic idea: Set up pairs of **shutter stations**, with pairs in line of sight. Then, code the letters to be transmitted:



Electrical telegraph



Observation

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

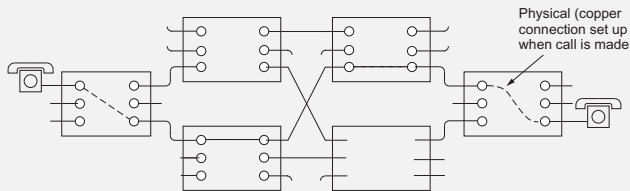
Note

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 \Rightarrow **circuit-switched network**.

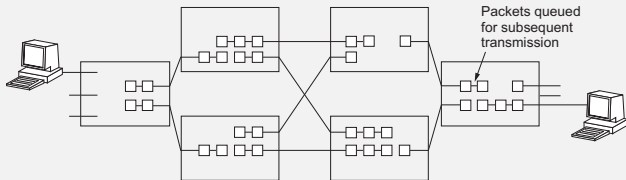


Modern telephony networks

Observation

In modern telephony networks, everything is **packetized**:

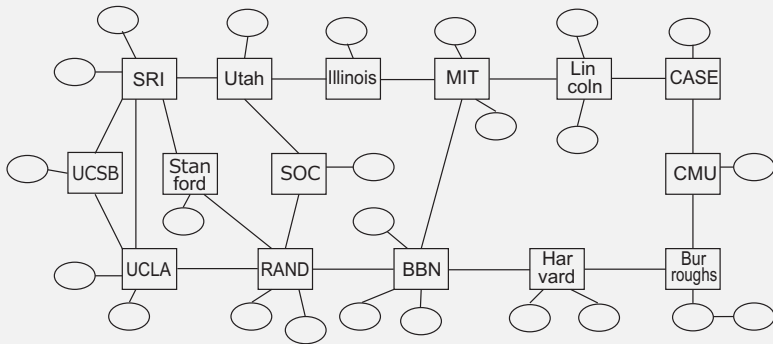
- Data (including **samples** from continuous media) is put into a **packet**.
- Packets are extended with address of destination and are independently **routed**.



From telephony to Internet

Next step

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

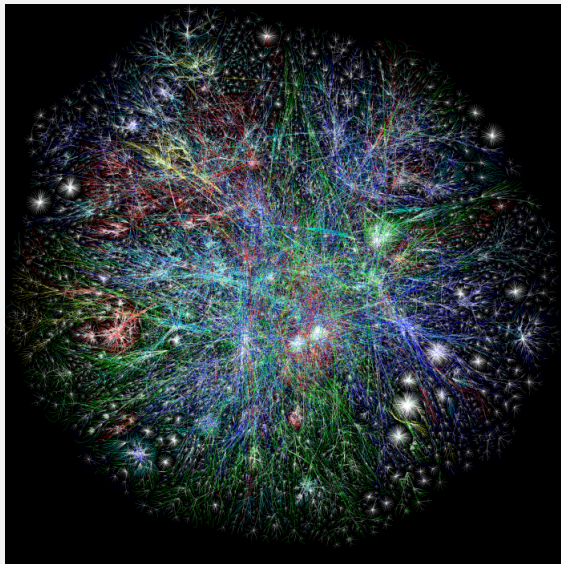


IMP = Interface Message Processor

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++

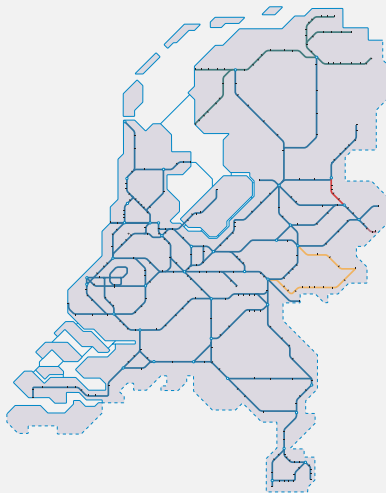
Blue N-America

Yellow S-America

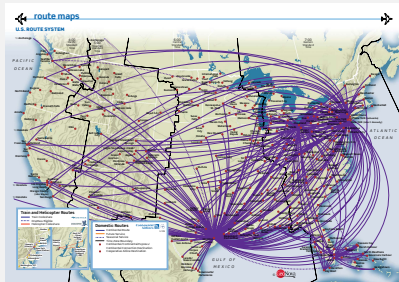
Cyan CIDR addr.

White Unknown

Network examples: Dutch railways



Network examples: Airline flights



Continental Airlines

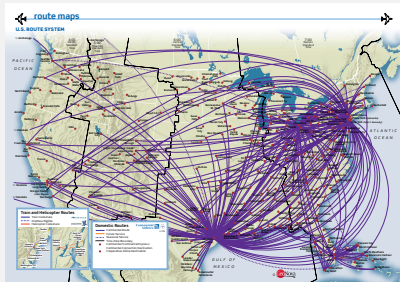


United Airlines

Question

What main differences can be seen?

Network examples: Airline flights



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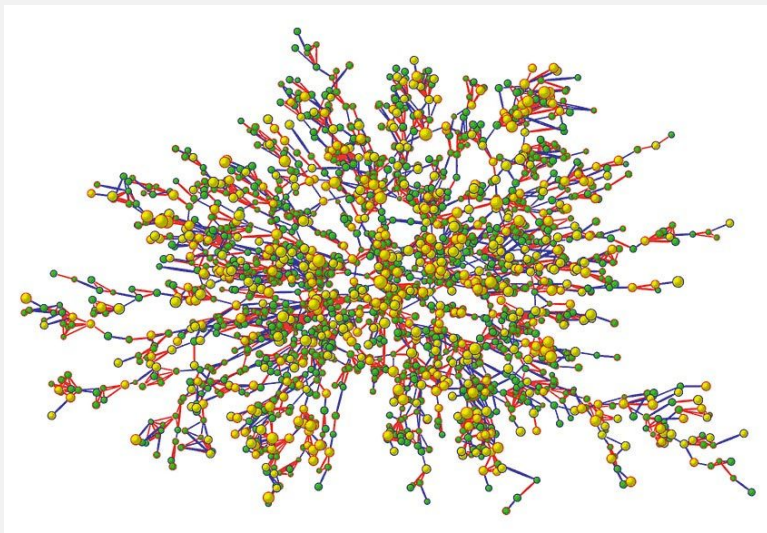


United Airlines

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Network examples: social networks



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