Graph Theory and Complex Networks: An Introduction

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Chapter 01: Introduction

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Contents

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

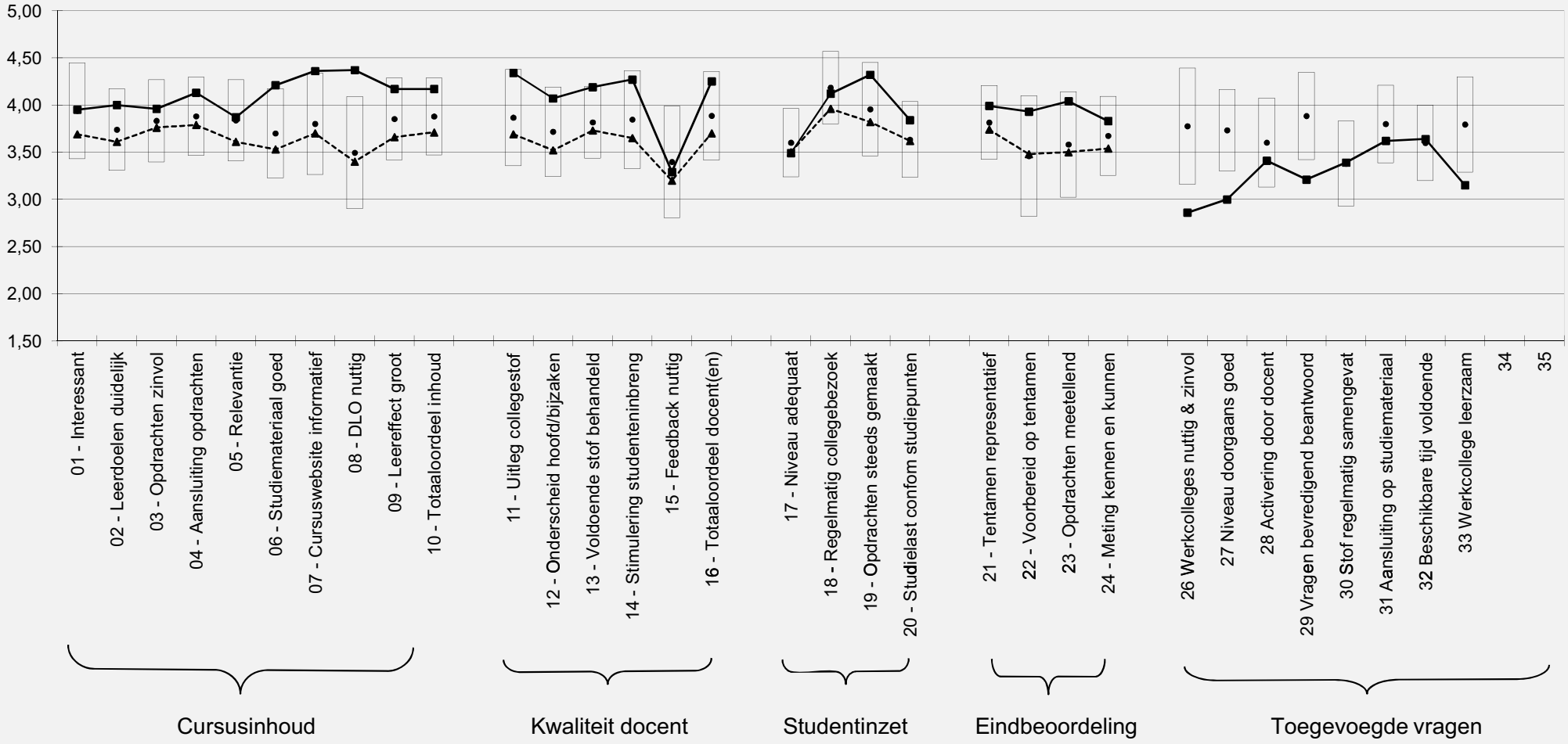
Some practical matters

- 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`

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?

The connected world

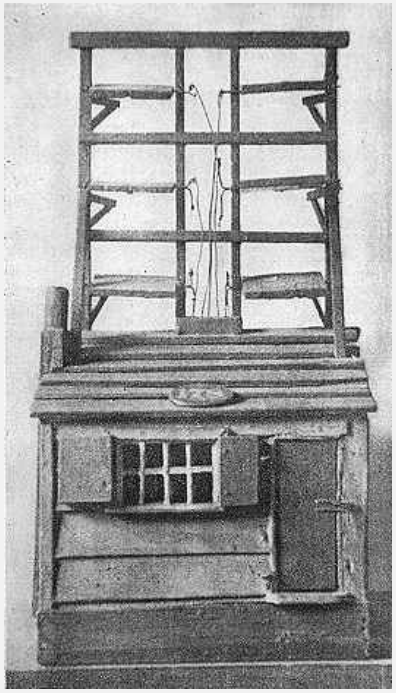
Observation

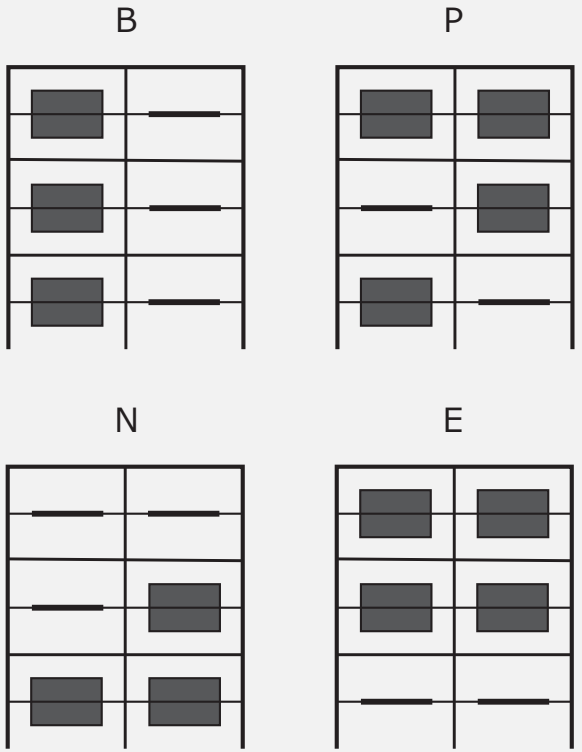
When it comes to connecting people, there is a long history of networks.

- 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.

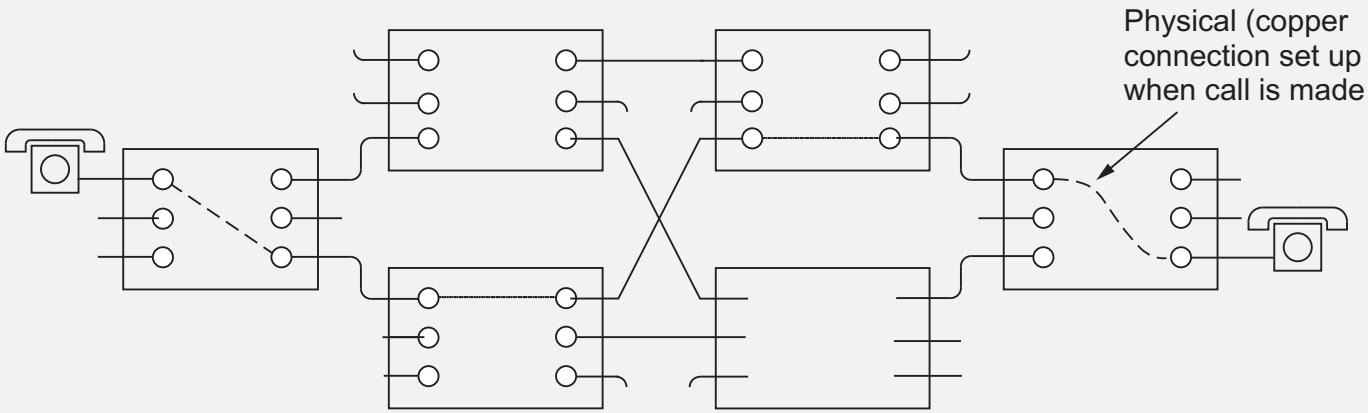
Note

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**.

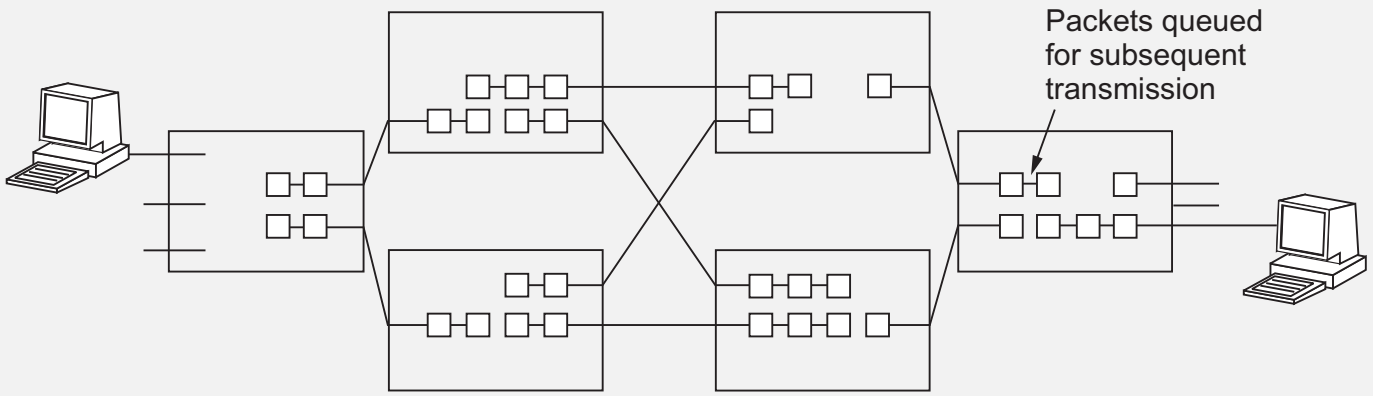


Modern telephony networks

Observation

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

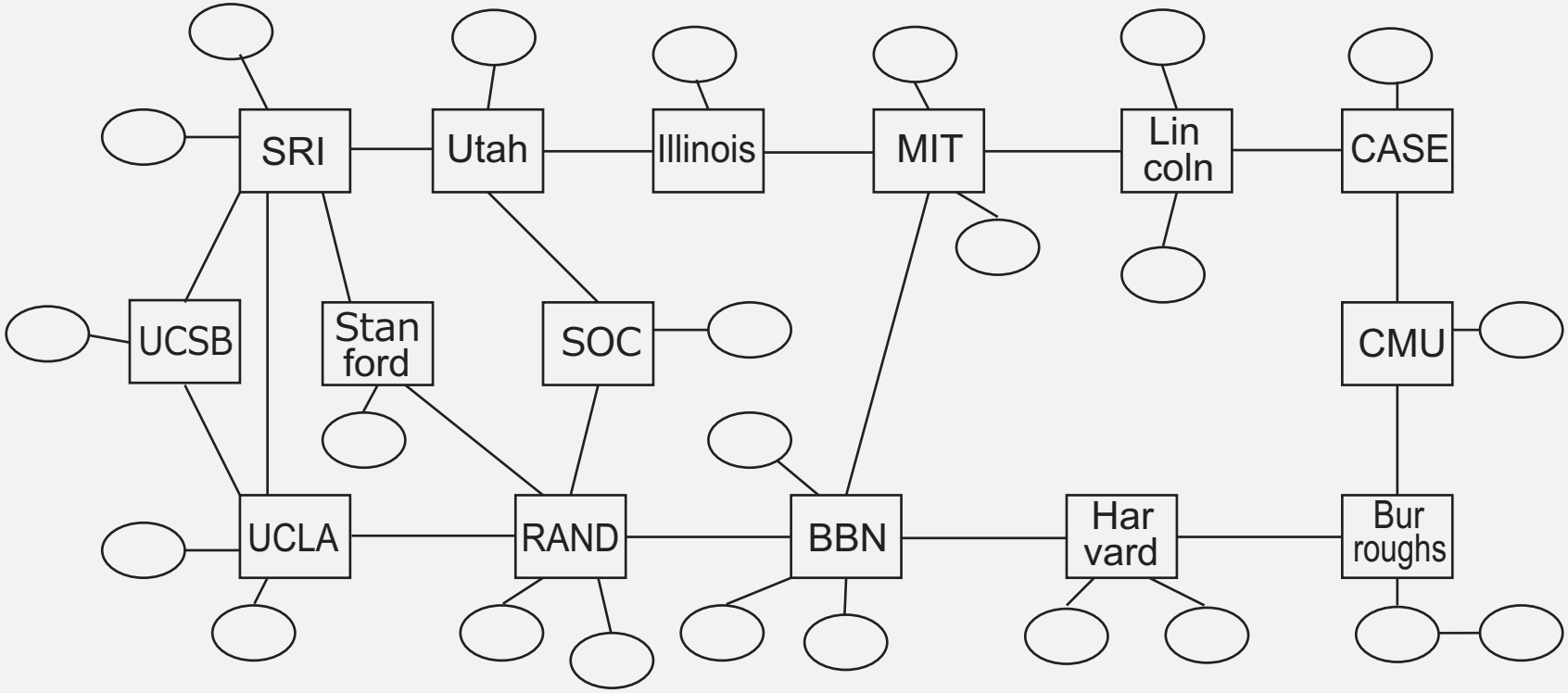
- Data (including samples from continuous media) is put into a **packet**.
- Packets are extended with address of destination and are independently routed.



From telephony to Internet

Next step

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

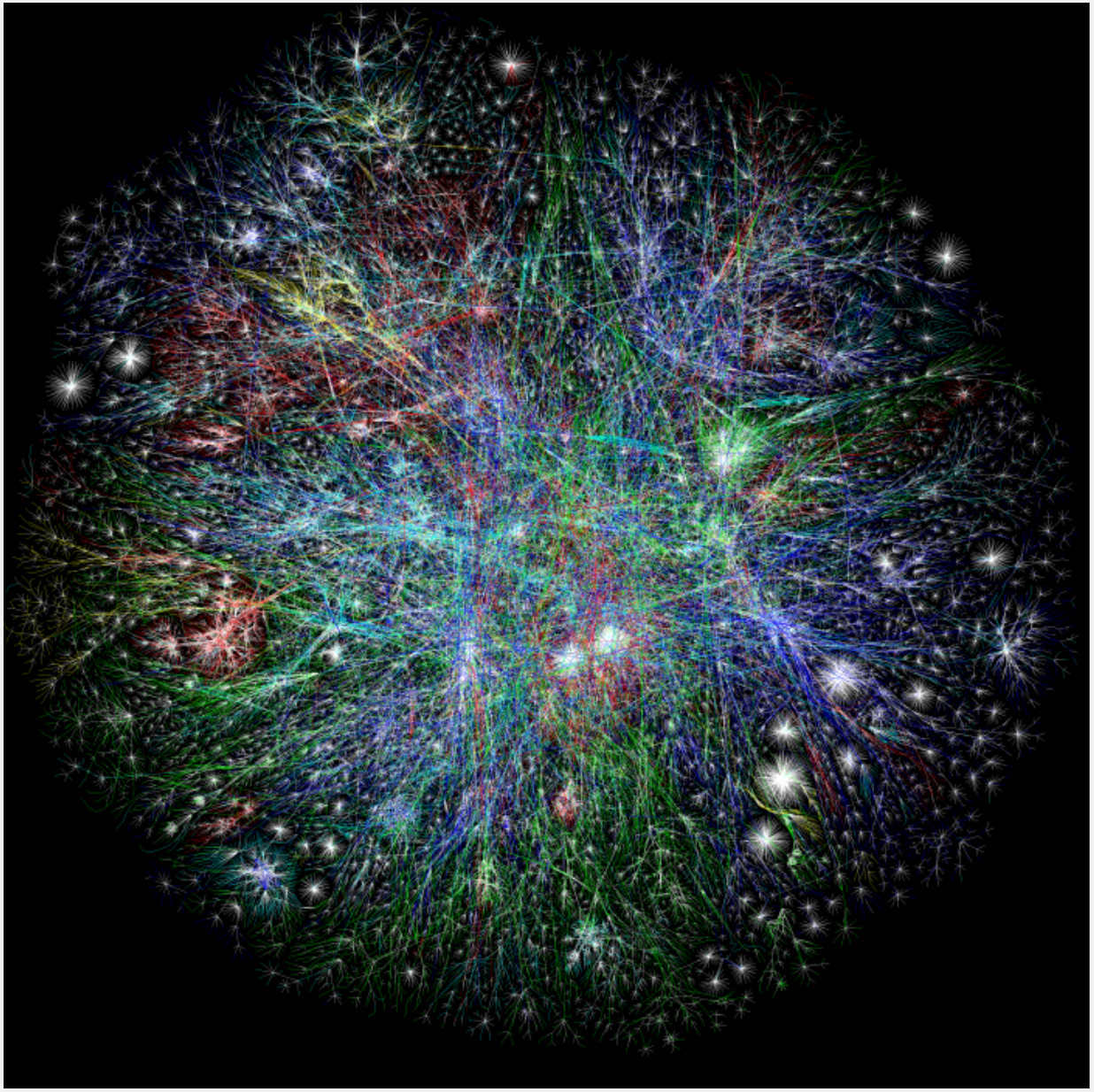


IMP = Interface Message Processor

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

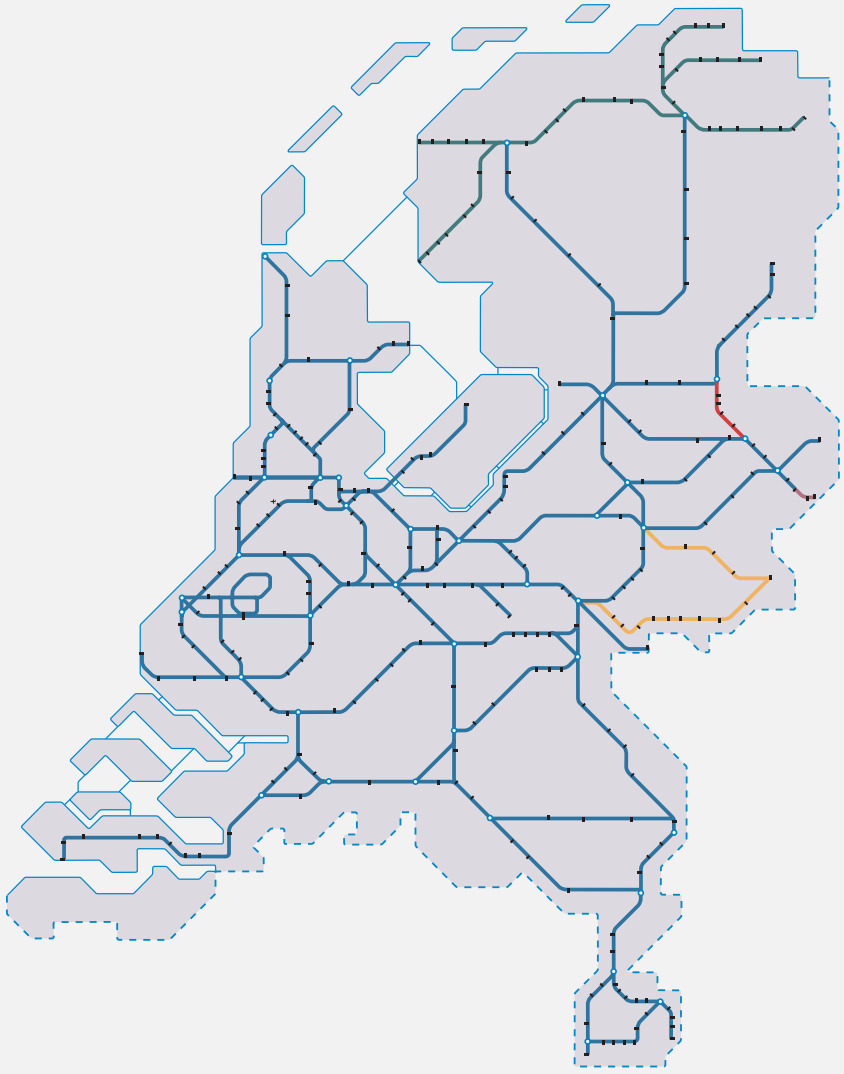
The modern Internet on display



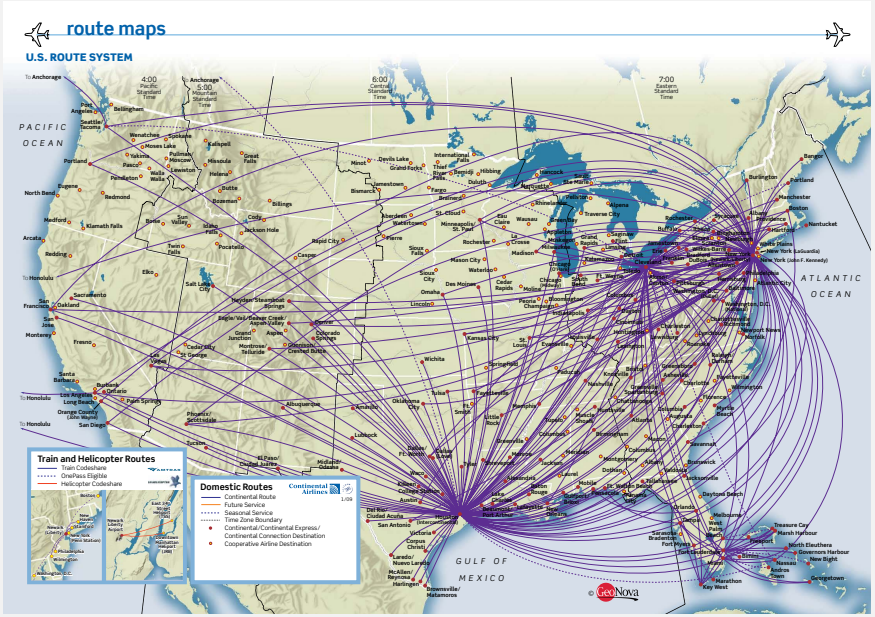
5 M edges
50 M routes

Red	Asia
Green	Europe++
Blue	N-America
Yellow	S-America
Cyan	CIDR addr.
White	Unknown

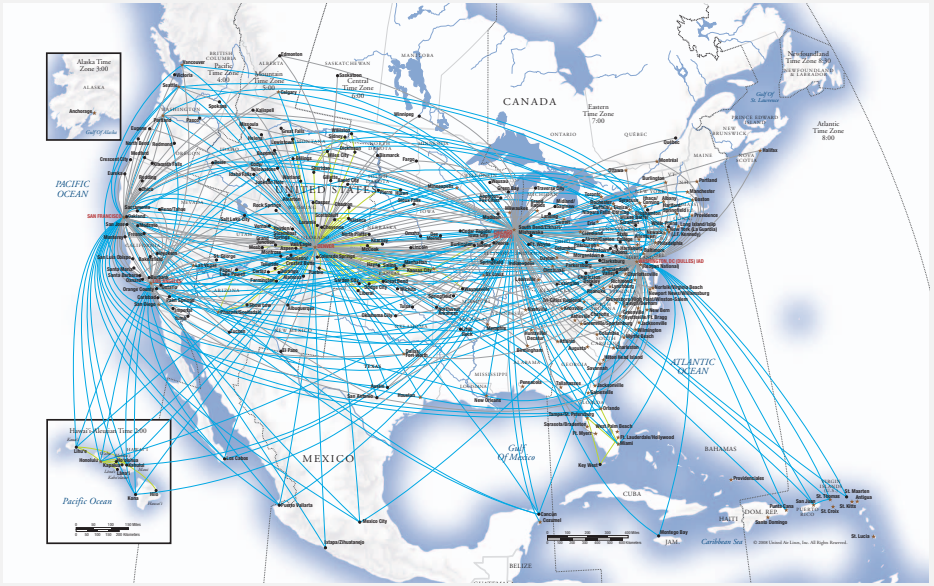
Network examples: Dutch railways



Network examples: Airline flights



Continental Airlines

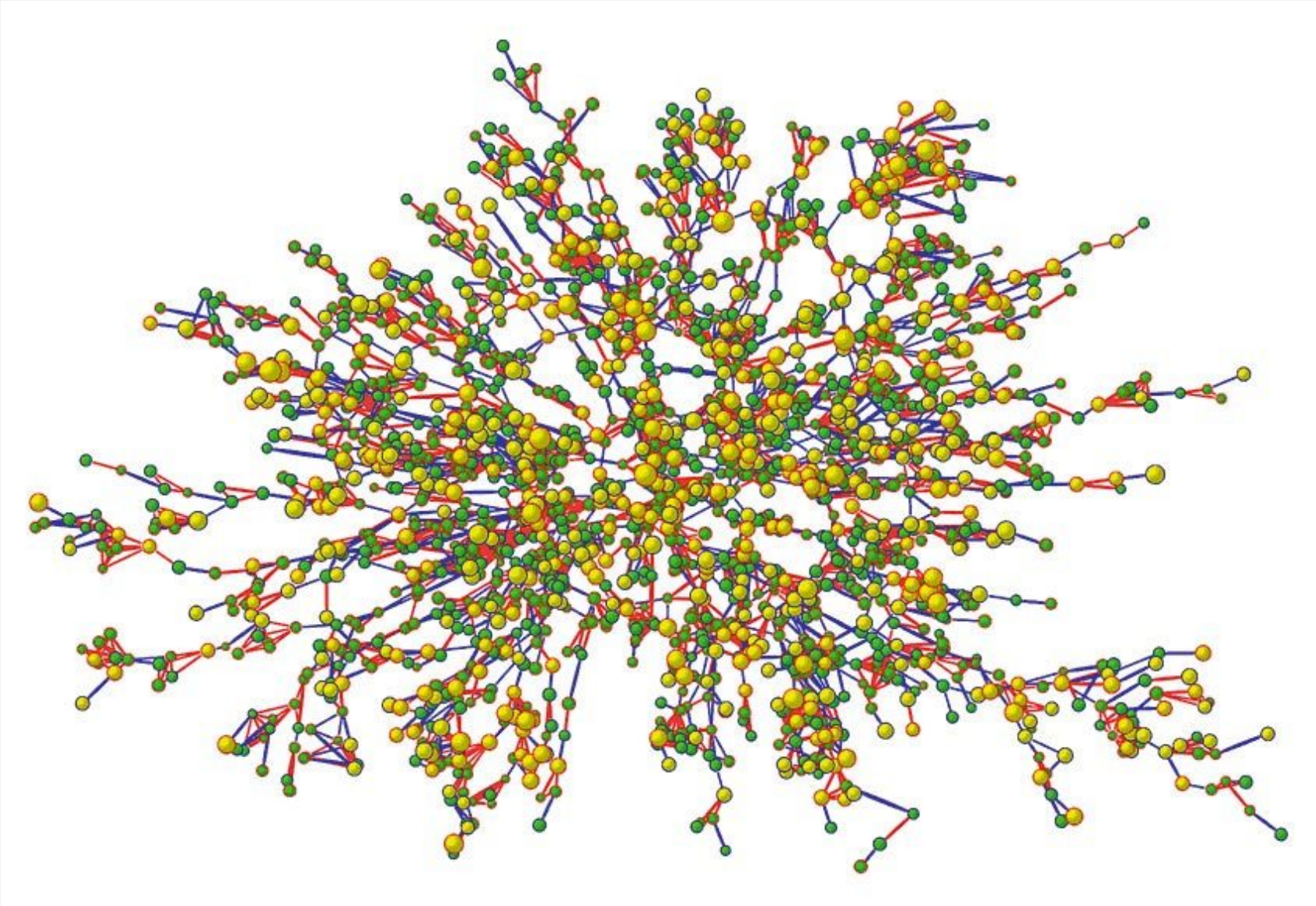


United Airlines

Question

What main differences can be seen?

Network examples: social networks



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