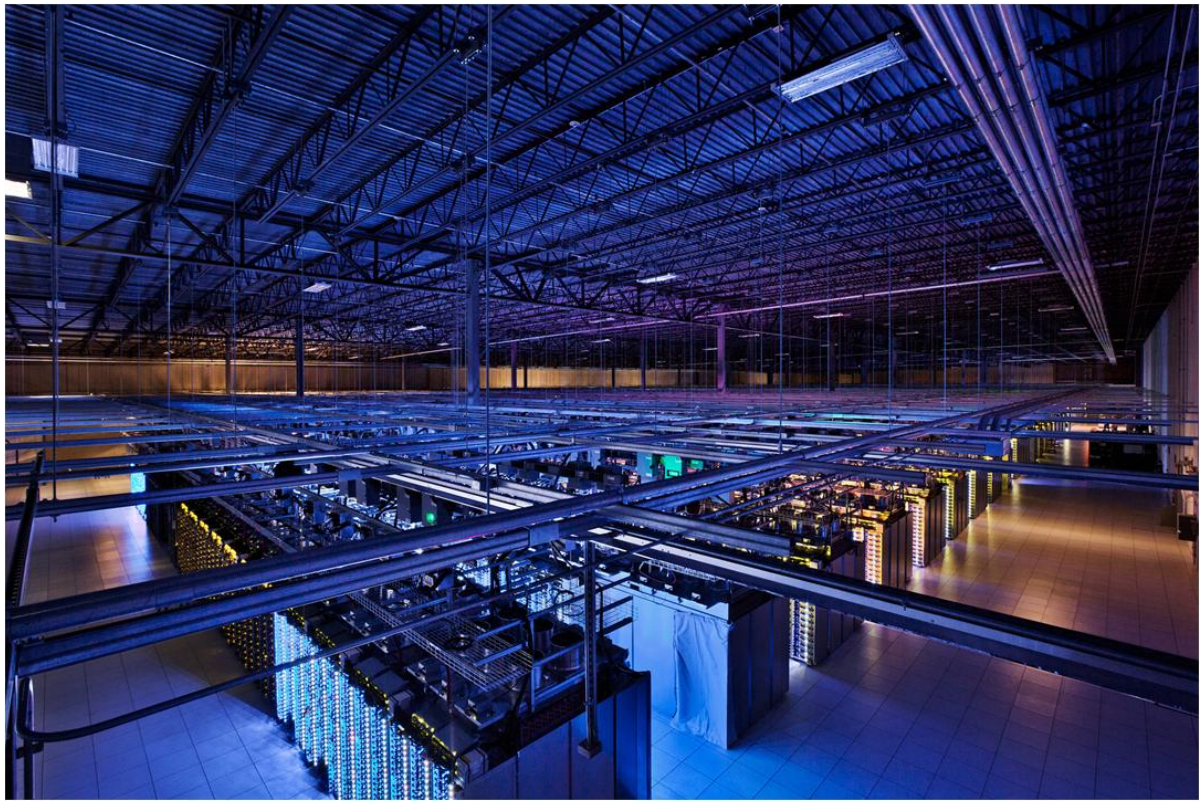
CWI
Centrum Wiskunde & Informatica

Large-Scale Data Engineering

Intro to LSDE,
Intro to Big Data & Intro to Cloud Computing



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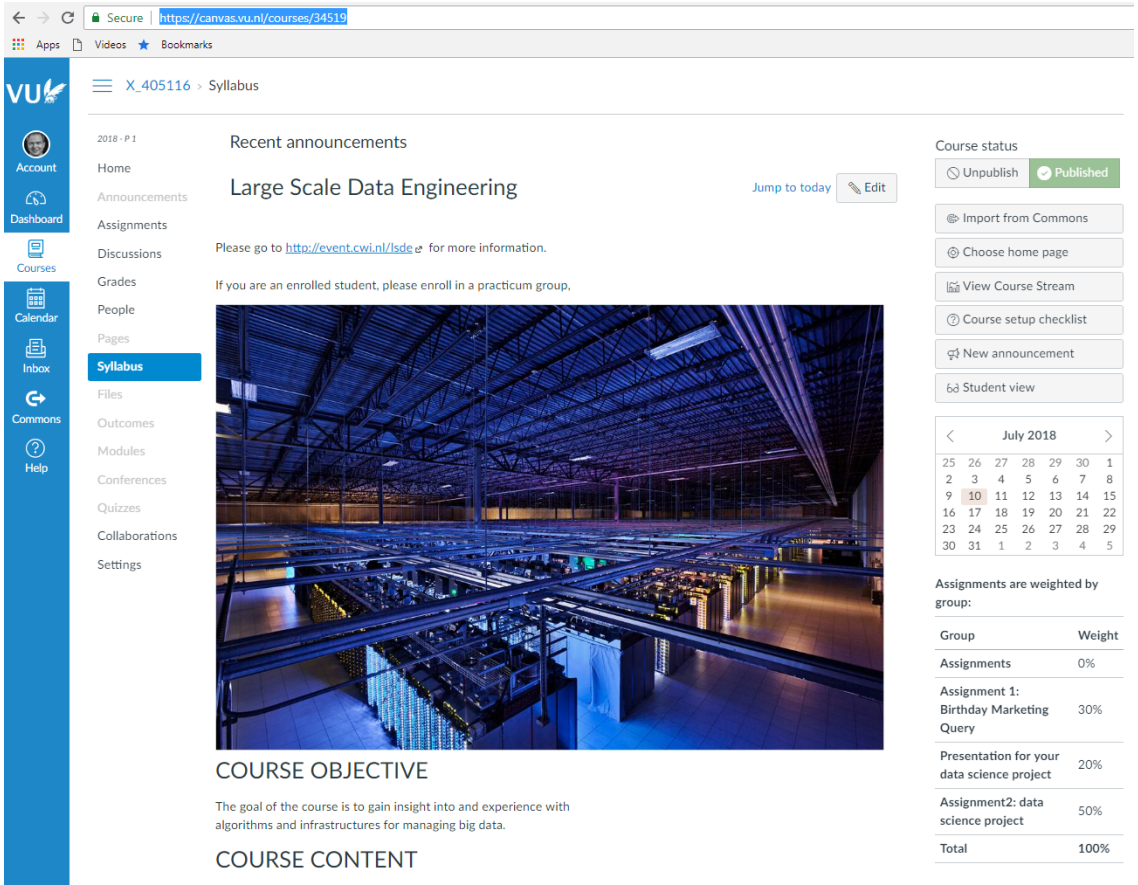
Administration

- Canvas Page
  - Announcements, also via email (pardon html formatting)
  - Turning in practicum assignments, Check Grades
- Contact: Slack & Skype lsde_course@outlook.com



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Goals & Scope

- The goal of the course is to gain **insight** into and **experience in** using hardware infrastructures and software technologies for **analyzing 'big data'**.

This course delves into the practical/technical side of data science

understanding and using large-scale data engineering to analyze big data

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Confronting you with the problems

method: struggle with assignment 1

- Confronts you with some data management tasks, where
  - naïve solutions break down
  - problem size/complexity requires using a cluster

- Solving such tasks requires
  - insight in the main factors that underlie algorithm performance
    - access pattern, hardware latency/bandwidth
  - these factors guided the design of current Big Data infratructures
    - helps understanding the challenges

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Learn technical material about large-scale data engineering

material: slides, scientific papers, books, videos, magazine articles

- Understanding the concepts

  hardware

  – What components are hardware infrastructures made up of?

  – What are the properties of these hardware components?

  – What does it take to access such hardware?

  software

  – What software layers are used to handle Big Data?

  – What are the principles behind this software?

  – Which kind of software would one use for which data problem?

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Obtain practical experience by doing a big data analysis project

method: do this in assignment 2

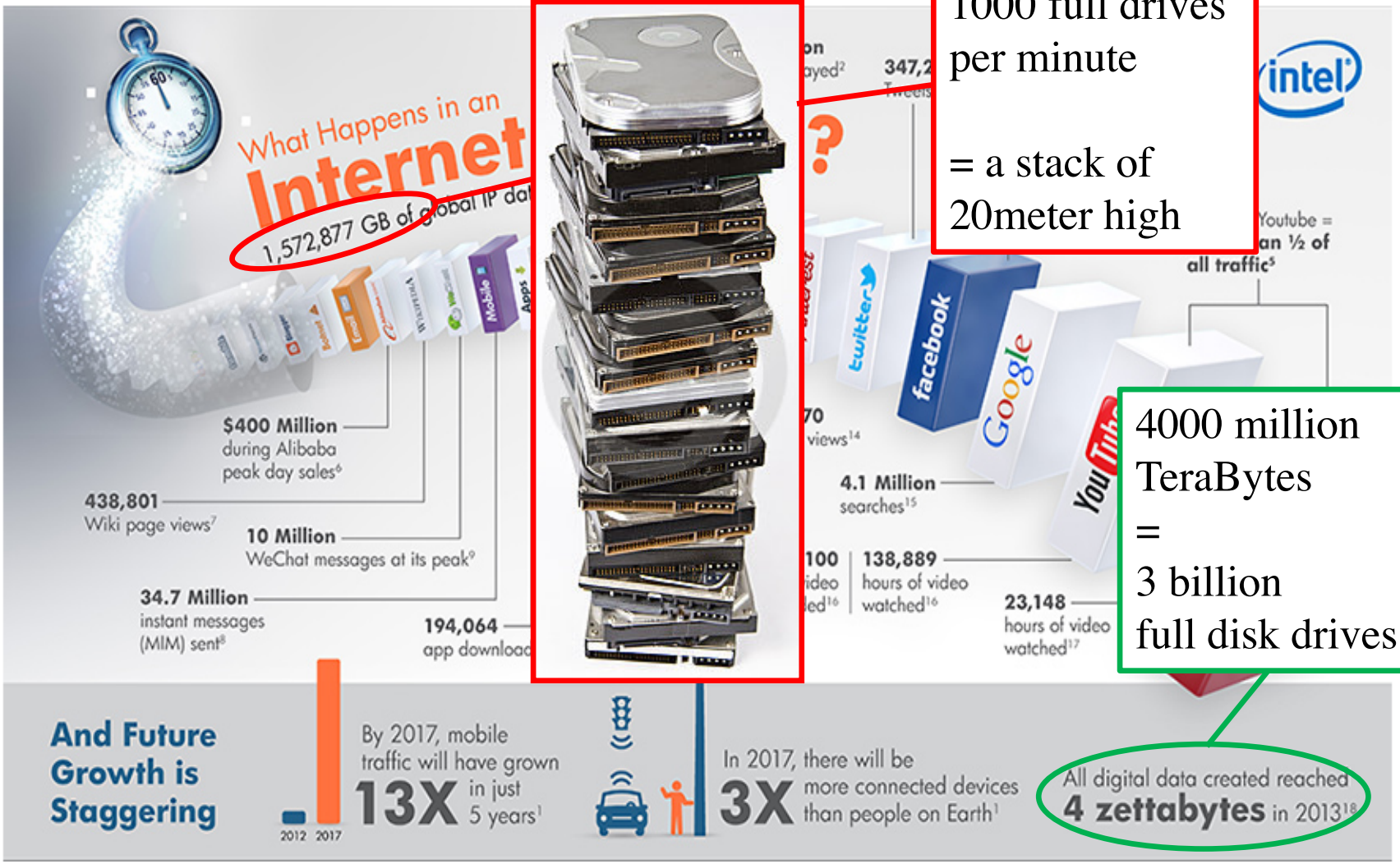
(code, report, 2 presentations, visualization website)

- Analyze a large dataset for a particular question/challenge
- Use the SurfSARA Hadoop cluster (90 machines) and appropriate cluster software tools

Your Tasks

- Interact in class, and in the slack channel (always)
- Start working on Assignment 1:
  - Register your github account on Canvas (now). Open one if needed.
  - 1a: Implement a ‘query’ program that solves a marketing query over a social network (deadline next week Monday night)
  - 1b: Implement a ‘reorg’ program to reduce the data and potentially store it in a more efficient form (deadline, one week after 1a).
- Read the papers in the reading list as the topics are covered (from next week on)
- Form practicum groups of three students (1c, deadline one week after 1b)
- Practice Spark on the Assignment1 query (in three weeks)
- Pick a unique project for Assignment 2 (in three weeks), FCFS in leaderboard order
  - Perform a data quick-scan and identify tools and literature
  - 8min in-class “planning” presentation (in four weeks)
  - conduct the project on a Hadoop Cluster (SurfSARA)
    - write code, perform experiments
  - 8min in-class “result/progress” presentation (in six weeks)
  - Submit code, Project Report and Visualization (deadline end of October)

The age of Big Data



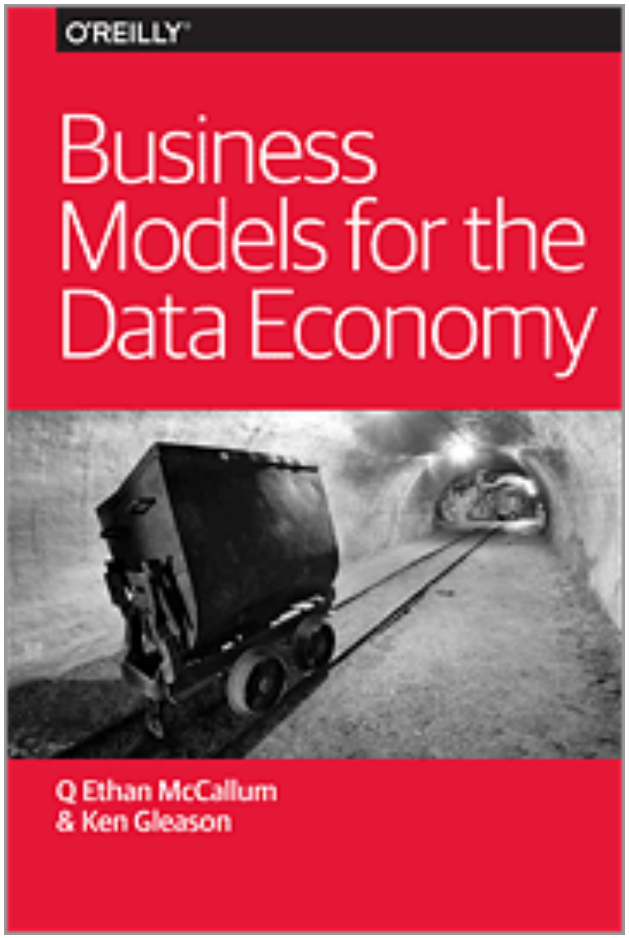
1500TB/min =
1000 full drives
per minute

= a stack of
20meter high

4000 million
TeraBytes
=
3 billion
full disk drives

“Big Data”

The Data Economy



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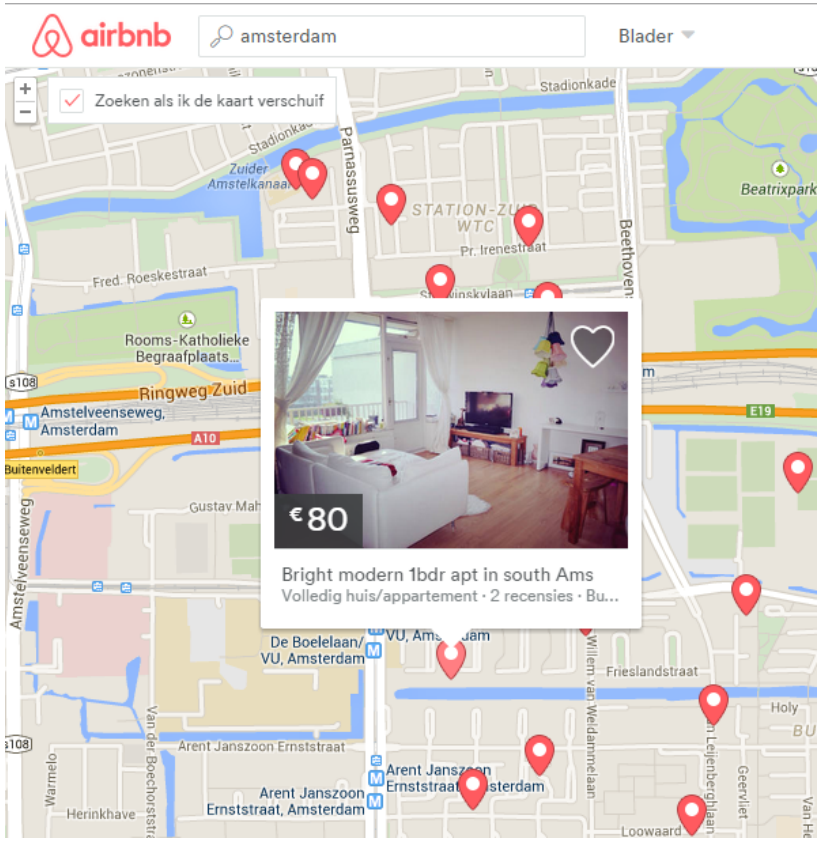
Disruptions by the Data Economy

UBER

EVERYONE'S PRIVATE DRIVER™



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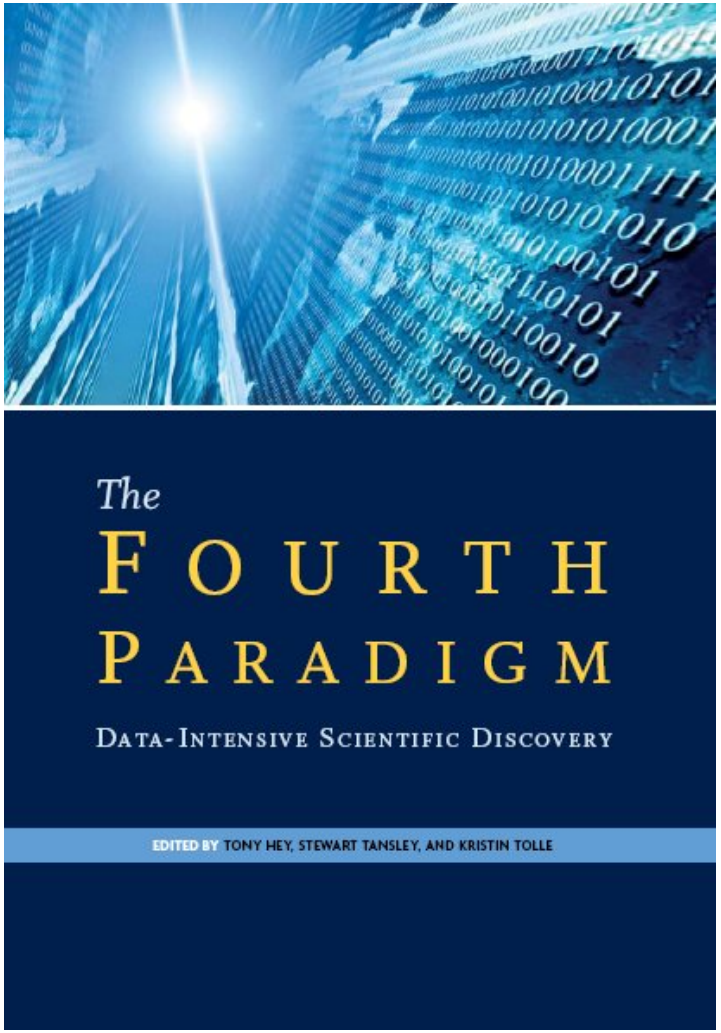
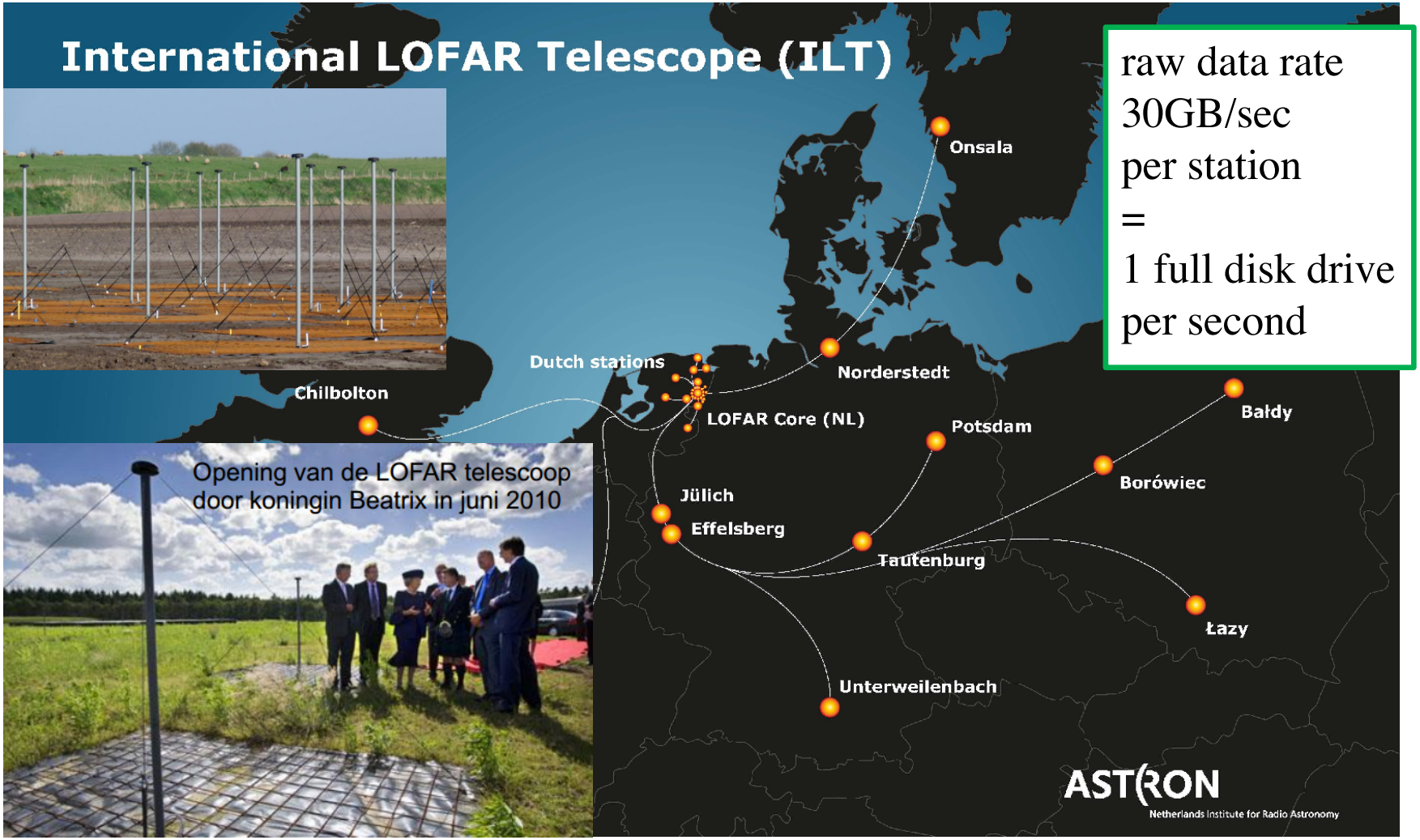
Data Disrupting Science



Scientific paradigms:

1. Observing
2. Modeling
3. Simulating
4. Collecting and Analyzing Data

Data Driven Science



raw data rate
30GB/sec
per station
=
1 full disk drive
per second

Big Data

- Big Data is a relative term
  - If things are breaking, you have Big Data
  - Big Data is not always Petabytes in size
  - Big Data for Informatics is not the same as for Google
- Big Data is often hard to understand
  - A model explaining it might be as complicated as the data itself
  - This has implications for Science
- The game may be the same, but the rules are completely different
  - What used to work needs to be reinvented in a different context

Big Data Challenges (1/3)

- **Volume** ➔ data larger than a single machine (CPU,RAM,disk)
  - Infrastructures and techniques that scale by using more machines
  - Google led the way in mastering “cluster data processing”
- Velocity
- Variety

Supercomputers?

- Take the top two supercomputers in the world today
  - Tiahne-2 (Guangzhou, China)
    - Cost: US$390 million
  - Titan (Oak Ridge National Laboratory, US)
    - Cost: US$97 million
- Assume an expected lifetime of five years and compute cost per hour
  - Tiahne-2: US$8,220
  - Titan: US$2,214
- This is just for the machine showing up at the door
  - Not factored in operational costs (e.g., running, maintenance, power, etc.)

Let's rent a supercomputer for an hour!

- Amazon Web Services charge US$1.60 per hour for a large instance
  - An 880 large instance cluster would cost US$1,408
  - Data costs US$0.15 per GB to upload
    - Assume we want to upload 1TB
    - This would cost US$153
  - The resulting setup would be #146 in the world's top-500 machines
  - Total cost: US$1,561 per hour
  - Search for (first hit): LINPACK 880 server

Supercomputing vs Cluster Computing

- Supercomputing
  - Focus on performance (biggest, fastest).. At any cost!
    - Oriented towards the [secret] government sector / scientific computing
  - Programming effort seems less relevant
    - Fortran + MPI: months do develop and debug programs
    - GPU, i.e. computing with graphics cards
    - FPGA, i.e. casting computation in hardware circuits
  - Assumes high-quality stable hardware
- Cluster Computing
  - use a network of many computers to create a ‘supercomputer’
  - oriented towards business applications
  - use cheap servers (or even desktops), unreliable hardware
    - software must make the unreliable parts reliable
  - focus on economics (bang for the buck)

Cloud Computing vs Cluster Computing

- Cluster Computing
  - Solving large tasks with more than one machine
    - Parallel database systems (e.g. Teradata, Vertica)
    - noSQL systems
    - Hadoop / MapReduce
- Cloud Computing

Cloud Computing vs Cluster Computing

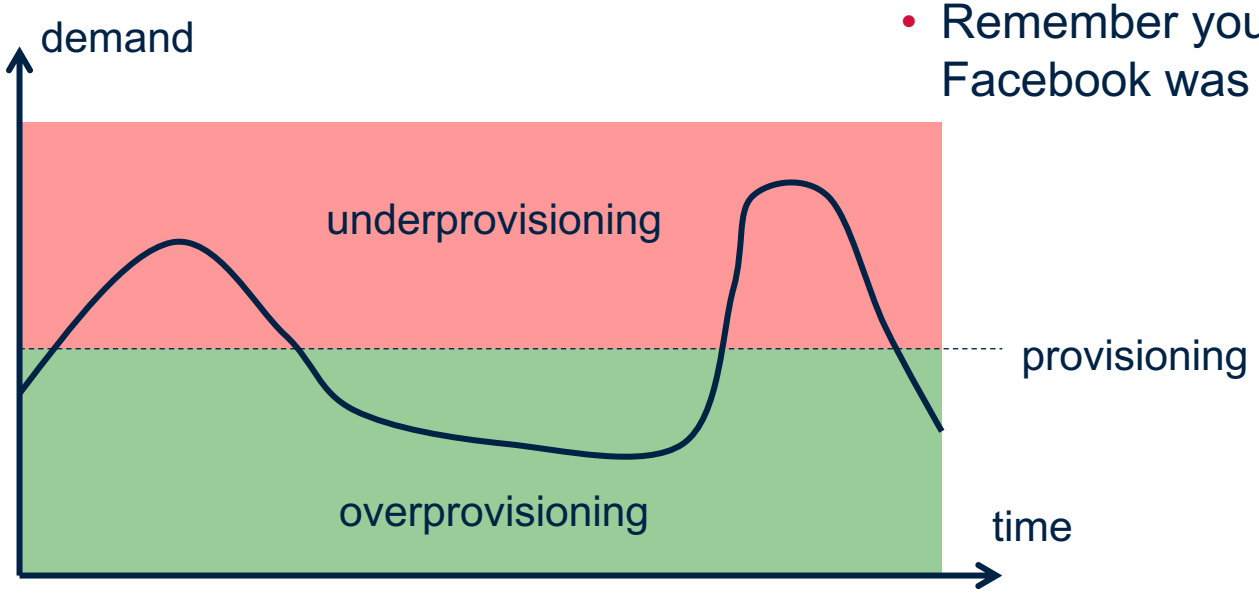
- Cluster Computing
- Cloud Computing
  - Machines operated by a third party in large data centers
    - sysadmin, electricity, backup, maintenance externalized
  - Rent access by the hour
    - Renting machines (Linux boxes): Infrastructure as a Service
    - Renting systems (Redshift SQL): Platform-as-a-service
    - Renting an software solution (Salesforce): Software-as-a-service
- {Cloud,Cluster} are independent concepts, but they are often combined!
  - We will do so in the practicum (Hadoop on Amazon Web Services)

Economics of Cloud Computing

- A major argument for Cloud Computing is pricing:
  - We could own our machines
    - … and pay for electricity, cooling, operators
    - …and allocate enough capacity to deal with peak demand
  - Since machines rarely operate at more than 30% capacity, we are paying for wasted resources
- Pay-as-you-go rental model
  - Rent machine instances by the hour
  - Pay for storage by space/month
  - Pay for bandwidth by space/hour
- No other costs
- This makes computing a commodity
  - Just like other commodity services (sewage, electricity etc.)

Cloud Computing: Provisioning

- We can quickly scale resources as demand dictates
  - High demand: more instances
  - Low demand: fewer instances
- Elastic provisioning is crucial



- Target (US retailer) uses Amazon Web Services (AWS) to host `target.com`
  - During massive spikes (November 28 2009 –"Black Friday") `target.com` is unavailable
- Remember your panic when Facebook was down?

Cloud Computing: some rough edges

- Some provider hosts our data
  - But we can only access it using proprietary (non-standard) APIs
  - **Lock-in** makes customers vulnerable to price increases and dependent upon the provider
  - Local laws (e.g. privacy) might prohibit externalizing data processing
- Providers may control our data in unexpected ways:
  - July 2009: Amazon remotely remove books from Kindles
  - Twitter prevents exporting tweets more than 3200 posts back
  - Facebook locks user-data in
  - Paying customers forced off Picasa towards Google Plus
- Anti-terror laws mean that providers have to grant access to governments
  - This privilege can be overused

Privacy and security

- People will not use Cloud Computing if trust is eroded
  - Who can access it?
    - Governments? Other people?
    - Snowden is the Chernobyl of Big Data
  - Privacy guarantees needs to be clearly stated and kept-to
- Privacy breaches
  - Numerous examples of Web mail accounts hacked
  - Many many cases of (UK) governmental data loss
  - TJX Companies Inc. (2007): 45 million credit and debit card numbers stolen
  - Every day there seems to be another instance of private data being leaked to the public

Big Data Challenges (2/3)

- Volume
- **Velocity** ➔ endless stream of new events
  - No time for heavy indexing (new data keeps arriving always)
  - led to development of data stream technologies
- Variety

Big Streaming Data

- Storing it is not really a problem: disk space is cheap
- Efficiently accessing it and deriving results can be hard
- Visualising it can be next to impossible
- Repeated observations
  - What makes Big Data big are repeated observations
  - Mobile phones report their locations every 15 seconds
  - People post on Twitter > 100 million posts a day
  - The Web changes every day
  - Potentially we need unbounded resources
    - Repeated observations motivates streaming algorithms

Big Data Challenges (3/3)

- Volume
- Velocity
- **Variety** ➔ Dirty, incomplete, inconclusive data (e.g. text in tweets)
  - Semantic complications:
    - AI techniques needed, not just database queries
    - Data mining, Data cleaning, text analysis (AI techniques)
  - Technical complications:
    - Skewed Value Distributions and “Power Laws”
    - Complex Graph Structures ➔ Expensive Random Access
    - Complicates cluster data processing (difficult to partition equally)
    - Localizing data by attaching pieces where you need them makes Big Data even bigger

Power laws

- This is **not** the 80/20 rule of skewed data (“80% of the sales are the 20% of the products”)
  - In a power law distribution, 80% of the data sales could well be in the “long tail” (the model is as large as the data).
- Modelling the head is easy, but may not be representative of the full population
  - Dealing with the full population might imply Big Data (e.g., selling all books, not just block busters)
- Processing Big Data might reveal power-laws
  - Most items take a small amount of time to process, individually
  - But there may be very many relevant items (“products”) to keep track of
  - A few items take a lot of time to process

Skewed Data

- Distributed computation is a natural way to tackle Big Data
  - MapReduce encourages sequential, disk-based, localised processing of data
  - MapReduce operates over a cluster of machines
- One consequence of power laws is uneven allocation of data to nodes
  - The head might go to one or two nodes
  - The tail would spread over all other nodes
  - All workers on the tail would finish quickly.
  - The head workers would be a lot slower
- Power laws can turn parallel algorithms into sequential algorithms

Big Data Challenges (3/3)

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Summary

- Introduced the notion of Big Data, the three V's
  - Volume, Velocity, Variety
- Explained differences between Super/Cluster/Cloud computing

Cloud computing:

- Computing as a commodity is likely to increase over time
- Cloud Computing adaptation and adoption are driven by economics
- The risks and obstacles behind it are complex
- Three levels:
  - Infrastructure as a service (run machines)
  - Platform as a service (use a database system on the cloud)
  - Software as a service (use software managed by other on the cloud)