Future Internet

Ankit Singla
Course staff

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Course Web site: keep a close eye on it!

https://ndal.ethz.ch/courses/fi.html

NDAL

Future Internet
The focus of the course is on principles, architectures, protocols, and applications used in modern networked systems. Example topics include:

- Video streaming services on the Internet
- How Web browsing could be made faster
- How the Internet’s protocols are improving
- Satellite-based networking (via SpaceX)
- The role of data centers in powering Internet services

A series of programming assignments will form a substantial part of the course grade. These will be engaging, timely, and both collaborative and competitive -- there will be leaderboards for teams of students to compete with their solutions on challenging problems.

Assessment
The course consists of lectures, exercises, and a written examination. The final assessment will be a combination of exercises and examination grades.

Staff
- Prof. Dr. Ankit Singla
- Debopam Bhattacharjee
- Melissa Licciardello
- Simon Kassing
- Vojislav Dukić
Grading and feedback

• Grade:
  • 50% from exam
  • 50% from 4 coding assignments

• Exercises
  - Only for feedback (not graded)
  - Exam will be similar in nature
Slack: register with your real name

https://join.slack.com/t/ndal-fi/signup
Communication with Slack

- Ask instructors and TAs questions
- Learn from fellow classmates
- Discuss class topics, and exciting networking news and developments

But also raise questions and discuss in class!
Exercises: Tue 14-15h, this room

Debopam Bhattacherjee
Simon Kassing
Melissa Licciardello
Vojislav Đukić

Ask questions, build on learnings from lectures, practice for exams …
Classroom etiquette

• Engage fully with the class
• Don’t use phones, laptops, tablets
  - Or sit in the back rows
• Questions encouraged at all times!
Plagiarism & cheating

• Zero tolerance policy
• Discussion of general approach is OK
• Do not copy / share code from anywhere
• Do not consult others’ code, solutions
• Do not post solutions publicly online
• When in doubt, ask!
There are always bugs ...

Help fix errors, problems!
Every week ...

- Lecture and discussion around a focus topic
- Introduction to next week’s topic
- Assigned readings on next week’s topic
- Exercises and programming assignments
What’s this course about?

• State of the art in networking practice
• State of the art in networking research
• Preparing to advance beyond the state of the art
Why study networking?
For the love of …

• … acronyms?

- BGP, OSPF, DNS, MAC, TCP, IP, WAN, DCTCP, ACL, AES, AP, SYN, ACK, LAN, CRC, HTTP, WWW, DoS, 4G, DHCP, ECN, RED, FIB, RIB, TLD, IETF, ICMP, IDS, IGMP, IS-IS, P2P, PHY, MTU, RTO, RDMA, WiFi, …
For the love of …

- … headers and bit / byte offsets?

[https://nmap.org/book/tcpip-ref.html]
For the love of ...

• ... terrible jokes?

A TCP/IP packet goes into a bar. It says, "I’d like a beer".
The barman asks, "A beer?" The packet responds, "Yes, a beer."
Why study networking?

1. Printing press, 1430s
2. Electricity, late 19th century
3. Penicillin, 1928
4. Semiconductor electronics, 1950s
5. Optical lenses, 13th century
6. Paper, second century
7. Internal combustion engine, ~1860
8. Vaccination, 1796
9. The Internet, 1960s
10. Steam engine, 1712
Everything depends on networking ...
BACKGROUND PAPER

Digital Dividends

Exploring the Relationship Between Broadband and Economic Growth

Michael Minges
ictData.org
Traceroute Path 1: from Guadalajara, Mexico to Washington, D.C.
HUGE impact on society

Internet traffic to and from Egypt on January 27 - 28. At 5:20 pm EST, traffic to and from Egypt across 80 Internet providers around the world drops precipitously.

[Arbor networks]
HUGE impact on society
HUGE impact on society

Starting at 3:35 UTC today (6:35am local time), approximately two-thirds of all Syrian networks became unreachable from the global Internet. Over the course of roughly half an hour, the routes to 40 of 59 networks were withdrawn from the global routing table.
This election is a total sham and a travesty. We are not a democracy!
Hot societal issue
Networking is a very hot space!
... with a lot of problems

KC Green (http://gunshowcomic.com/648)
Innovation in the design of networks

Link-state network carrying only LAs (e.g., 10/8)

Internet

VL2 @ Microsoft, ACM SIGCOMM’09
Greenburg, Hamilton, Jain, Kandula, Kim, Lahiri, Maltz, Patel, Sengupta

“Introducing data center fabric, the next-generation Facebook data center network”, Alexey Andreyev, 2015
Figure 4: 100Gbps user-user topology. Cities are marked in red and towers in grey. Blue links (thin) require no additional towers, green links (thicker) require 1 additional tower and red links (thickest) require 2 additional towers at both ends.

**User-User:** This category comprises of traffic between users that does not traverse a data center/cloud. This includes interactive applications and other user-user flows. We focus on users in 120 population centers, which covers ~85% of the US population. The weight associated with a city $i$ is $p_i$. A flow between cities $i$ and $j$ has a weight of $p_i \times p_j$.

**Data Center-Data Center (DC-DC):** We use Google data centers as an example for building a low latency network connecting data centers. We consider all the 6 publicly available Google data center locations - Berkeley, SC; Council Bluffs, IA; Douglas County, GA; Lenoir, NC; Mayes County, OK; and Dallas, OR. Since the characteristics of low-latency traffic between data centers is not available, we provision equal capacity between all pairs of data centers. All flows are assigned a weight of 1.

**User-Data Center (User-DC):** Each of the 120 cities is assumed to send traffic to the closest Google DC. This traffic is weighted by the population of the city, $p_i$.

Initially, we study each of the traffic classes separately to understand their characteristics. The user-user traffic class/network is chosen as a representative when the classes have similar performance for a metric. Finally, we present results on the performance of a combined network that connects all cities and data centers and handles all classes of traffic.

4.2 Microwave network analysis

In this section, we report on experiments aimed at evaluating the relationships between various parameters of the microwave network such as stretch, bandwidth, cost etc.

4.2.1 Stretch analysis

During the topology design phase, the goal is to minimize stretch while maintaining a low cost. Since there are only 120 links in the user-DC topology, each city is connected to the closest data center using the shortest available path. The DC-DC topology has 15 links connecting the 6 Google data centers along shortest paths. The population-weighted stretch for user-DC topology is 1.05313. The mean stretch between Google DCs with equal weights for all data centers is 1.03.

For the user-user topology, if all pairs of cities are connected using shortest paths, the population-weighted stretch is 1.02417. However, this topology is expensive and has a large number of links with low utilization. In order to optimize cost, we start with the minimum spanning tree between 120 cities and repeatedly add links that minimize the mean stretch. In Figure 6, we plot the CDF of population-weighted stretch with increasing number of city-level links in the topology. We observe that when 400 city-level pairs are connected using shortest paths, the mean stretch of the topology is 1.04869. Also, the incremental improvement in mean stretch when adding more links decreases significantly beyond this point. Hence, we choose the user-user topology with 400 city-level links for the rest of the experiments.

4.2.2 Cost Per GB

In order to estimate the cost per Gigabyte of traffic on the network, we rely on cost estimates in [37] and conversations...
Innovation in the management of networks

Software-defined network

“Network OS”

Logically centralized controller

Data plane API
Innovation in extracting performance

Routing and traffic engineering
Innovation at the application layer

Video quality vs. buffering

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Also good for entrepreneurship
What are the BIGGEST problems?
Physicists have superconductivity ...

[Inspired by Brighten Godfrey at UIUC]

[Pia Jensen Ray. Figure 2.4 in Master’s thesis, "Structural investigation of La(2-x)Sr(x)CuO(4+y) - Following staging as a function of temperature". Niels Bohr Institute, Faculty of Science, University of Copenhagen. Copenhagen, Denmark, November 2015. DOI:10.6084/m9.figshare.2075680.v2]
CS theorists have $P \neq NP$
What’s networking’s grand challenge?

• 6.0 / 6.0 ?
• My research project(s)?
• ?

Security? Reliability?
Performance? Automation?