EP1100

Data Communication and Computer Networks

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Today's lecture

- Overview
  - From data communication to computer networks
  - Network functions
- Applications and user requirements
- Outline of the course

Information, data and communication

- Define the terms *information*, *data* and *communication*
  - Take a few minutes to think on your own
  - Discuss two and two for five minutes
  - Compare notes with another pair
    - Discuss and refine for five minutes

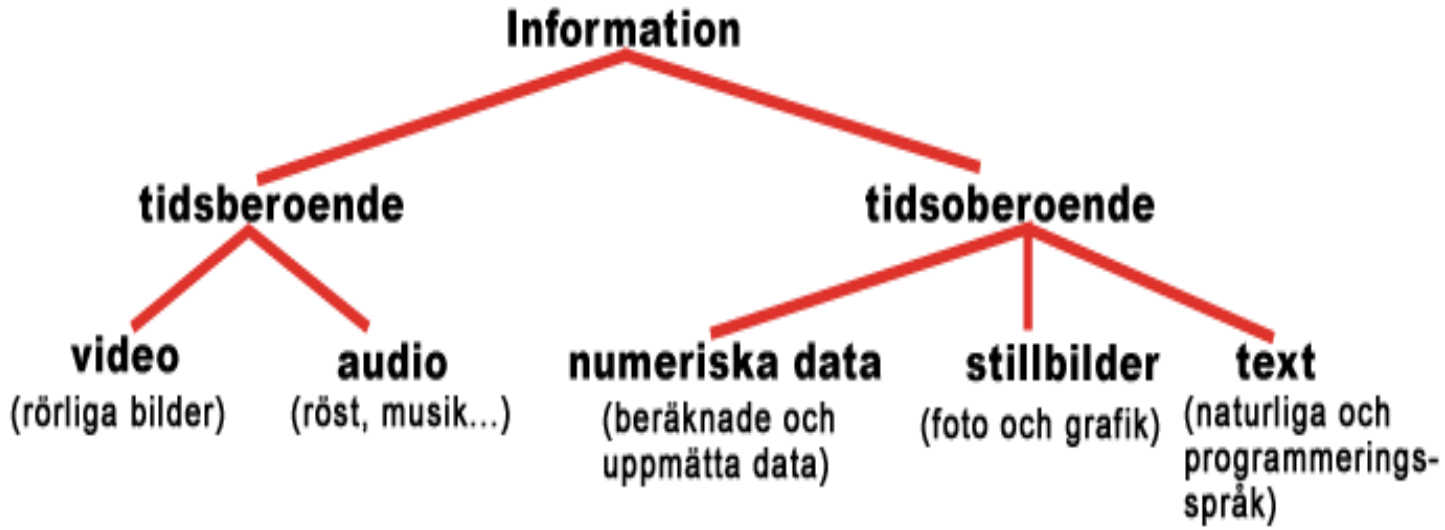
Information, data and communication

- Information—many meanings
  - Negative entropy—information reduces uncertainty
  - An answer to a specific question
  - ...
- Data
  - Representation of information, often represented in binary digits, *bits*
    - One bit may have values 0 and 1
- Communication
  - The process of sharing data
  - Telecommunication
    - Communication at a distance
      - ”Tele” is ”far” in Greek
    - Historically speech by telephony and text by telegram
    - Sound, pictures, video, text, sensor data, ... everything?

Information – a technical definition

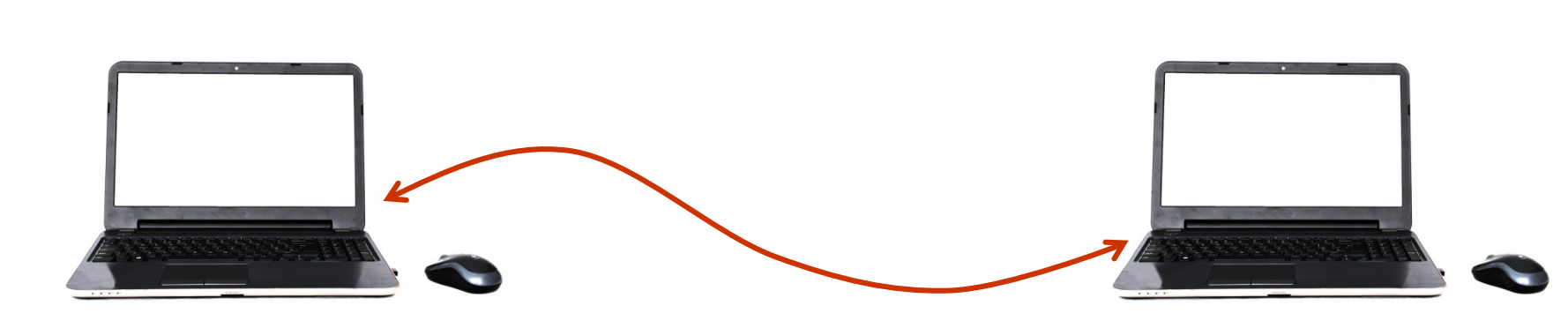
- Information represents one alternative
  - To represent one of N alternatives requires $\lceil \log_2 N \rceil$ bits
  - Example: the letters in the Swedish alphabet can be represented by 5 bits ($2^5 = 32$)
- Context known by sender and receiver
  - The alternatives are well defined
    - Knowing that given five bits represent a letter from the Swedish alphabet, for instance
  - Could take much data to communicate context!

Information and information rate



- Time independent information
  - *An amount* of bits [b] or bytes (8 bits) [B]
- Time dependent information
  - Might be sampled continuous signals
    - Shannon-Nyquist criterion: twice the highest frequency of the signal
    - Quantized to a finite number of signal levels
  - A *bit rate* (or data rate) in bits per second [b/s, bit/s, bps]
    - Sampling frequency [1/s] × bits per sample [b]
- Prefices: kilo (k) 10^3, mega (M) 10^6, giga (G) 10^9, tera (T) 10^{12}, peta (P) 10^{15}, exa (E) 10^{18}, zetta (Z) 10^{21}, yotta (Y) 10^{24}, … googol 10^{100}

Data communication



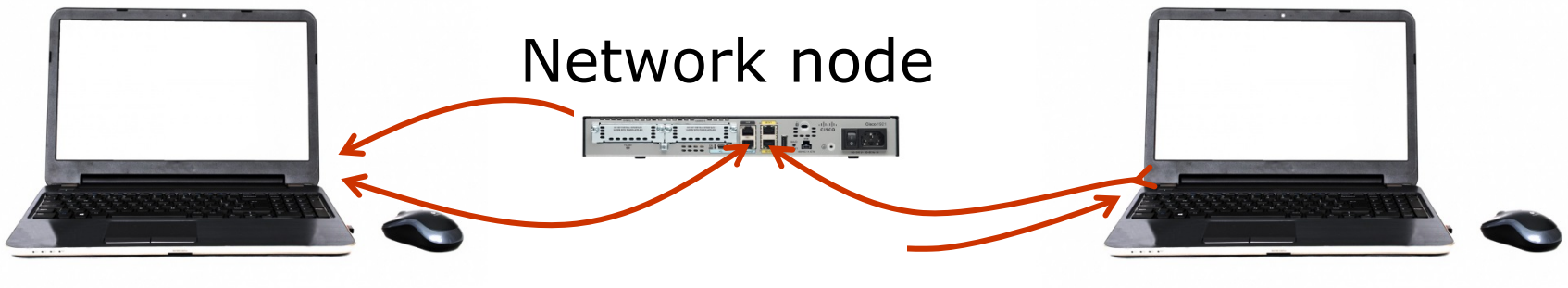
- Definition: Sending and receiving data
- What *functions* are needed to get two computers to communicate?
  - Discuss two and two for five minutes
    - List functions
  - Compare notes with another pair for five minutes
  - Discuss and merge lists

Data Communication

1. Some form of transmission medium for a signal
   - Electric signal over a electric cable
   - Light signal in an optical cable or free space
   - Radio signal in wave guide or free space
2. Data is transferred by the signal
   - Forming the signal to represent data at sender
     - Different amplitudes, frequencies and phases of the signal
   - Receiver detects signal form and maps to data values
     - Data is recreated at the receiver
     - Errors due to… what?
     - Attenuation, noise, distortion
3. Data communication functions for links
   - Signals regeneration and amplification to reduce errors
   - Framing to mark beginning and end of message
     - Separate idle link from noise
   - Flow control to match sending and receiving data rates
   - Handling of errors

- → Delivery of data *frames* from point to point over a *link*

Computer networks



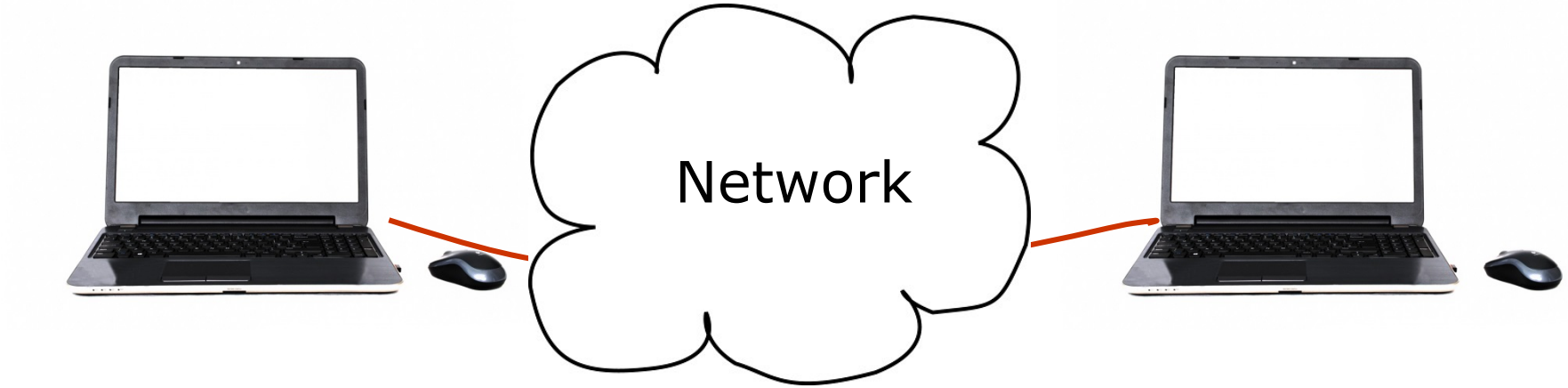
- Definition: Transferring data over a network between computers
- What additional *functions* are needed to get *any* two (or more) computers to communicate?
  - Discuss two and two for five minutes
    - List functions
  - Compare notes with another pair for five minutes
  - Discuss and merge lists

Network functions

1. Addressing to identify receiver, sender and network nodes
   - Unique identifier within the network
   - Could point to where the device is located (a locator)
2. Routing to find a path between sender and receiver
   - Learn the topology (map) of the network
   - Compute the best route through the network
3. Switching to forward frames from incoming to outgoing link
   - Sort frames to different outputs according to destination
   - Sorting rule given by routing information
4. Buffering and scheduling to store frames and decide which to send
   - Compensate for differences in speed
   - Multiplexing of frames from different inputs to each output
5. Management and network operations to supervise the network

- → Delivery of data *frames* from any point to any point over a *network*

Network services



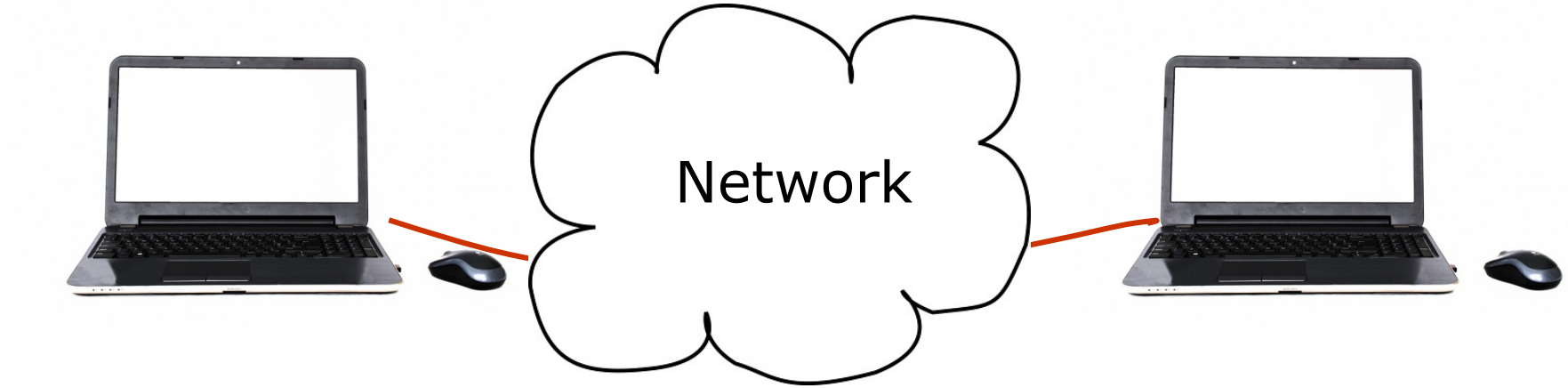
- Definition: providing communication to processes
- What additional *functions* are needed to get any two (or more) *processes* to communicate?
  - Discuss two and two for five minutes
    - List functions
  - Compare notes with another pair for five minutes
  - Discuss and merge lists

Network services

1. Name service to find address of the other party
2. Multiplexing of data from processes onto the network connection
   - The address only identifies the computer, not the application
   - Segmentation and reassembly of application data
3. Flow and congestion control and error handling
   - Similar to data communication for a link, now for a virtual link (a route)
   - Congestion relates to overload in the network; flow control to the receiver
4. Security, integrity and privacy of communication to make trustworthy services

- → Delivery of data from any process to any process over a *network*

Applications

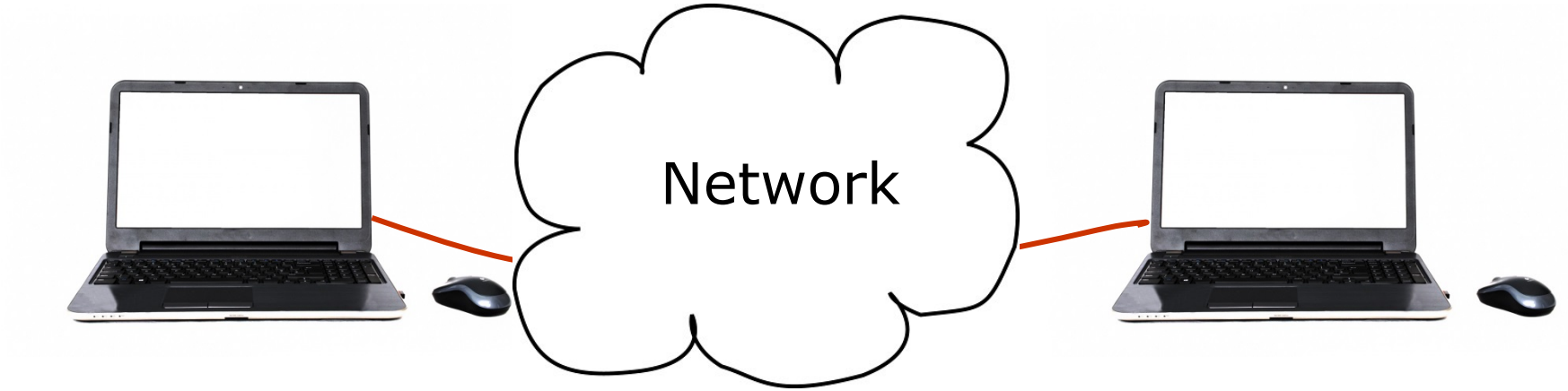


- The use of the communication to humans or other systems
  - To send or to fetch data
  - Defines the purpose of the communication
  - Examples
    - Email
    - Web
    - Spotify
    - Skype

    Email, Web: Standardized

    Spotify, Skype: Proprietary
- Applications and users put requirements on network services

Applications

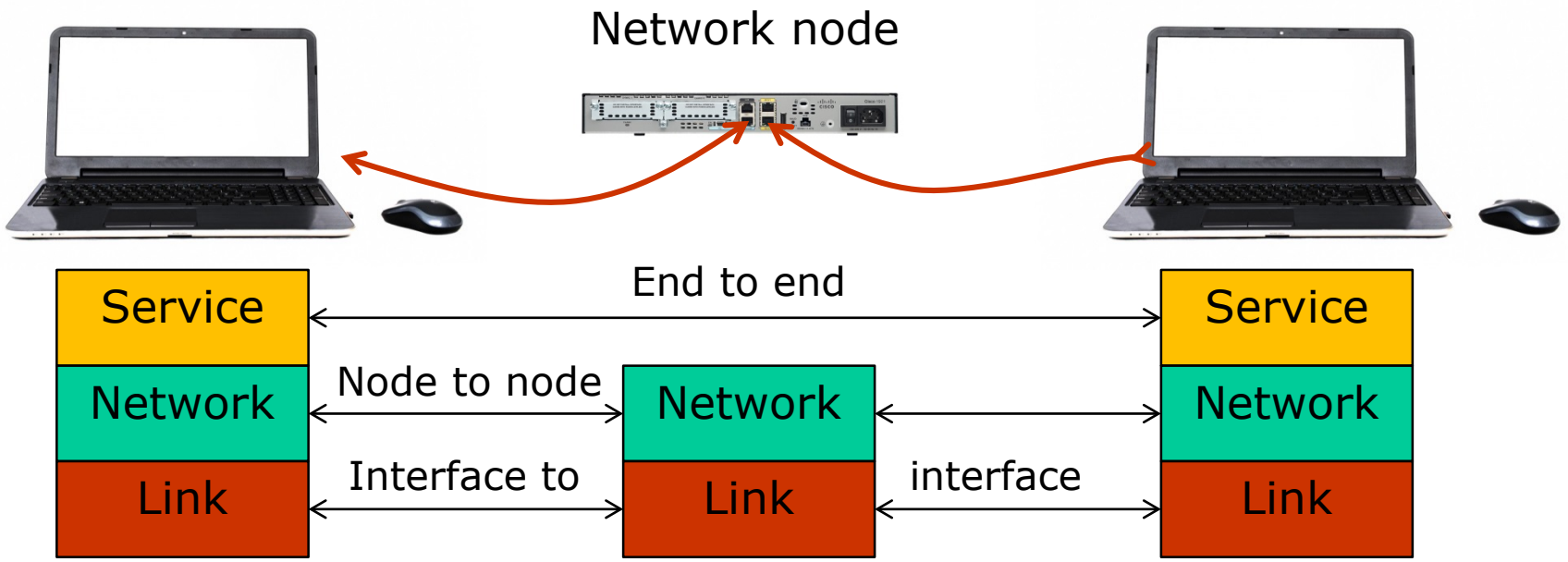


- Applications and users put requirements on network services
- What service requirements should be considered when users and applications communicate?
  - Discuss two and two for five minutes
    - List metrics and quality aspects
  - Compare notes with another pair for five minutes
  - Discuss and merge lists

Application and user requirements

- Quality
  - Delay (a k a latency)
  - Data loss and errors
  - Reliability
  - Availability
  - Security
  - Privacy
- Cost
  - Information
    - The contents
    - Eg pay-per-view
  - Service
    - Resources
      - Network access
      - Connection time
      - Data volume
    - Management
      - Booking
      - Directory services
      - Security

Protocol and architecture



- System functions bundled into protocols that are organized in layers
  - Peer-to-peer processes between protocols at the same layer in different nodes
  - Abstraction of concerns: a lower layer provides a service to an upper layer
- Communication between adjacent layers in the same node
  - Well-defined interfaces that are part of the protocol specification
  - Data is transferred by passing application and network data through layers
    - down (sending) or up (receiving)

Summary

- Data communication provides transmission of data frames over a link
- Computer networks provide network services to computers
- Protocol and architecture
- Applications and user requirements

Goals with the course

- Learn principles
  - Data communication
    - Transmission
    - Flow and error control
    - Multiplexing
    - Medium access
  - Networking
    - Addressing and routing
    - Switching and buffering
  - End to end protocols
    - Multiplexing
    - Flow and congestion control
    - Applications
  - Network architecture
    - Protocols – How system functions are performed
    - How the protocols provide services
- Learn about examples of actual networks
  - IEEE 802 local area networks
  - TCP/IP and the Internet
- To build a basis for further networking courses and for application domains

Further courses in networking

- Intermediate
  - Internetworking, EP2120
  - Wireless Networks, EP2950
  - Queuing Theory and Teletraffic Systems, EP2200
  - Management of Networks and Networked Systems, EP2300
  - Networked System Security, EP2500
- Advanced
  - Principles of Wireless Sensor Networks, EL2745
  - Performance Analysis of Communication Networks, EP2210
  - Advanced Networked Systems Security, EP2510
- Degree Project in Communication Networks, Second Level, EP240X

Course structure

- Lectures
  - Overview of material, emphasis on understanding
  - Interactive, can be tailored to wishes (if expressed!); class exercises
- Recitations
  - Solving problems
  - Opportunity to clarify concepts
- Continuous examination
  - Four self studies: need to complete and pass all
    - Bonus points for hand-ins *not* requiring reworking
  - Four case studies: need to complete and pass all
    - Groups of up to three students per group
  - Five mini-examinations: cumulative result gives course grade
    - ETCS grades A to E passing, Fx and F fail
      - — Students with Fx may pass course with grade E based on extra examination
      - — Bonus points can only be used to improve grade E to B during this course round
    - Mini-exams 1 and 5 are mandatory since they check first and last self study exercises
    - Mini-exam 5 is cumulative over entire course

Course structure

- Three laboratory assignments
  - Hands-on work in selected topics
  - Preparation for the laboratory with homework

- Final exam for those not passing continuous examination
  - Friday March 15 from 14:00 to 18:00.
  - Five problems of 10 points each
    - Tests deep understanding of concepts, algorithms and technologies
    - No simple mapping of lectures and book chapters to problem
    - ETCS grades A to E passing, Fx and F fail
      - — Students with Fx may pass course with grade E based on extra examination
      - — Bonus points valid for those who have passing grade

Course Material

Online material, course books and articles

- EP1100 i Scalable Learning, (enrollment key QTFWF-78400)
- Larry Peterson, Bruce Davie, *Computer Networks: A Systems Approach*, 2012
- Olivier Bonaventure, *Computer Networking: Principles, Protocols and Practice*
- Jean Walrand, Shyam Parekh, *Communication Networks: A Concise Introduction*
- Dimitri Bertsekas, Robert Gallager, *Data networks*, 1992
- Gunnar Karlsson, *Modern telekommunikation*, Studentlitteratur, 1997 (utdrag)
- Andrew Russel, The internet that wasn't, *IEEE Spectrum*, August 2013

Extra videos and voluntary reading

- Andrew Tanenbaum och David Wetherall, Computer Networks 5e: Video lectures by David Wetherall
- Paul Baran, The beginnings of packet switching: some underlying concepts, IEEE Communications Magazine, Volume: 40, Issue: 7, Pages: 42 - 48, 2002
- Louis Pouzin och Hubert Zimmermann, A tutorial on protocols, Proceedings of the IEEE, Volume: 66, Issue: 11, Pages: 1346 - 1370, 1978
- Hamed Haddadi och Olivier Bonaventure (editors), *Recent Advances in Networking,* ACM SIGCOMM eBook, Volume 1, August 2013
- Benedict Carey, How we learn: *The surprising truth about when, where and why it happens, Random House*, 2014: Appendix: Eleven essential questions.

Your Responsibilities

- Continuous attention
  - Active learning! Continuous examination
  - Much to read!
  - Time to let it sink in
- Important messages in Canvas
  - Also given at the lectures
  - You are responsible for staying updated!
- Be on time for the exams in class, for mini-exams, oral presentations and obey deadlines for the handins
- Course responsible can be reached through email at gk@kth.se subject EP1100
- Course evaluation