School of Computing Science

60 YEARS OF COMPUTING AT GLASGOW

# Introduction to Networked Systems

## Networked Systems (H)

## Lecture 1

# Lecture Outline

- Course Administration
  - Aims, Objectives, Intended Learning Outcomes
  - Course Outline
  - Labs and Assessment
  - Reading List
- Introduction to Networks

# Course Administration

# Contact Details and Website

- Lecturers
  - Dr Colin Perkins (Glasgow) and Dr Ian Thng (Singapore)
  - No scheduled office hours – make appointments by email to discuss the course outside scheduled lecture or lab times if necessary
- Lecture notes and other material on online:
  - https://csperkins.org/teaching/2016-2017/networked-systems/ (or on the School's Moodle site)
  - Paper handouts will not be provided – the act of taking notes helps learning

# Aims and Objectives

- To introduce the fundamental concepts and theory of communications
- To provide a solid understanding of the technology that supports modern networked computer systems
- To introduce low-level network programming, and give students practice with systems programming in C;
- To give students the ability to evaluate and advise industry on the use and deployment of networked systems

# Intended Learning Outcomes

- By the end of the course, students should be able to:
  - Describe and compare capabilities of various communication technologies and techniques;
  - Know the differences between networks of different scale, and how these affect their design;
  - Describe the issues in connecting heterogeneous networks;
  - Describe importance of layering, and the OSI reference model;
  - Understand demands of different applications on quality of service requirements for the underlying communication network;
  - Demonstrate an understanding of the design and operation of an IP network, such as the Internet, and explain the purpose and function of its various components; and
  - Write simple low-level communication software, showing awareness of good practice for correct and secure programming

# Course Outline

| Week | Lecture Slot 1 | Lecture Slot 2 | Laboratory Session |
|---|---|---|---|
| 1 | Introduction | Protocols and layers | Network programming |
| 2 | Physical layer | Data link layer | Further network programming |
| 3 | Media access control | Bridging | |
| 4 | Internetworking | Addressing | |
| 5 | Intra-domain routing (1) | Intra-domain routing (2) | |
| 6 | Inter-domain routing | Transport layer | Understanding the topology of the network |
| 7 | TCP | Congestion control | |
| 8 | UDP | NAT | |
| 9 | Transport security | Writing secure code | |
| 10 | Higher-layer protocols | | |

The aims of the labs are to improve your understanding of the network, of network programming using the Sockets API, and to practice systems programming in C.

# Assessment

- Assessed exercises: 20%
  - Mixture of formative and summative exercises
  - Don’t leave summative exercises to the last minute: they’re designed to be completed over several weeks, allowing time for thought and reflection on the material, and are too large to complete in a rush in a couple of days
- Examination: 80%
  - Exam format: answer all three questions

# Assessment of Coursework (1)

- The coursework is intended to improve your C programming skills, as well as your understanding of networks
  - The marking scheme will assess the C code you submit, in addition to your understanding of networking
    - Code that is over-complex, convoluted, or difficult to follow will receive fewer marks than code that gives identical results, but that is cleanly structured and easy to understand
    - Assessment will explicitly target C code quality and correctness; marks will be deducted for poor code style, bugs, and security vulnerabilities – even if the submission gives the correct answer
  - Note that networked code often exhibits bugs that are difficult to demonstrate in small-scale laboratory tests, but can be found by expert inspection:
    - Race conditions due to use of POSIX threads with incorrect locking
    - Race conditions due to passing socket file descriptors incorrectly
    - Buffer overflows or other security vulnerabilities
    - …

    Just because a program works in your tests doesn't necessarily mean it's bug free – your tests may be insufficient to show the bug

# Assessment of Coursework (2)

- Student feedback from a previous year:

  > "It seems to me that the assessment was more of an exercise in writing perfect C code than understanding networked systems"

- Today's network is an *extremely* hostile environment
- Writing networked systems that are both secure and safe to deploy *is* "an exercise in writing perfect C code" – if you learn nothing else from this course, that understanding is crucial

# Assessment of Coursework (3)

- The University code of assessment specifies penalties for late submission, and for non-adherence to submission instructions

- These penalties will be strictly applied

- If you have special circumstances that will affect your submissions, you must inform the lecturer *before* the deadline

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**Assessed Coursework**

| | | | | |
|---|---|---|---|---|
| Course Name | | | | |
| Coursework Number | | | | |
| Deadline | Time: | 4:30pm | Date: | |
| % Contribution to final course mark | | | This should take this many hours: | |
| Solo or Group ✓ | Solo | | Group | |
| Submission Instructions | | | | |
| Who Will Mark This? ✓ | Lecturer | Tutor | Other | |
| Feedback Type? ✓ | Written | Oral | Both | |
| Individual or Generic? ✓ | Generic | Individual | Both | |
| Other Feedback Notes | | | | |
| Discussion in Class? ✓ | Yes | No | | |
| Please Note: This Coursework cannot be Re-Done | | | | |

**Code of Assessment Rules for Coursework Submission**

Deadlines for the submission of coursework which is to be formally assessed will be published in course documentation, and work which is submitted later than the deadline will be subject to penalty as set out below. The primary grade and secondary band awarded for coursework which is submitted after the published deadline will be calculated as follows:

(i) in respect of work submitted not more than five working days after the deadline
   a. the work will be assessed in the usual way;
   b. the primary grade and secondary band so determined will then be reduced by two secondary bands for each working day (or part of a working day) the work was submitted late.

(ii) work submitted more than five working days after the deadline will be awarded Grade H.

Penalties for late submission of coursework will not be imposed if good cause is established for the late submission. You should submit documents supporting good cause via MyCampus.

**Penalty for non-adherence to Submission Instructions is 2 bands**

**You must complete an "Own Work" form via**
**http://www.dcs.gla.ac.uk/socs-online for all coursework**
**UNLESS submitted via Moodle**

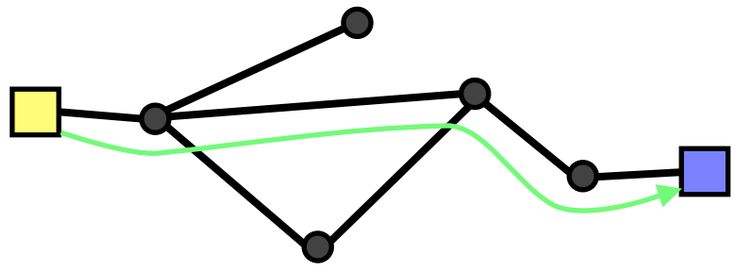
# Required Reading

- Any good text on computer networks, for example:
  - Peterson and Davie, Computer Networks: A Systems Approach, 5th Edition, Morgan Kaufman, 2011, ISBN 0123851386
  - Kurose and Ross, Computer Networking: A Top-Down Approach, 6th Edition, Addison-Wesley, 2012, ISBN 0273768964
  - Tanenbaum and Wetherall, Computer Networks, 5th Edition, Prentice Hall, 2010, ISBN 0132553171
  - Bonaventure, Computer Networking: Principles, Protocols and Practice, online textbook (http://cnp3book.info.ucl.ac.be/index.html)
- You are expected to read-along with the lectures – the lectures introduce the concepts, and the books provide detail

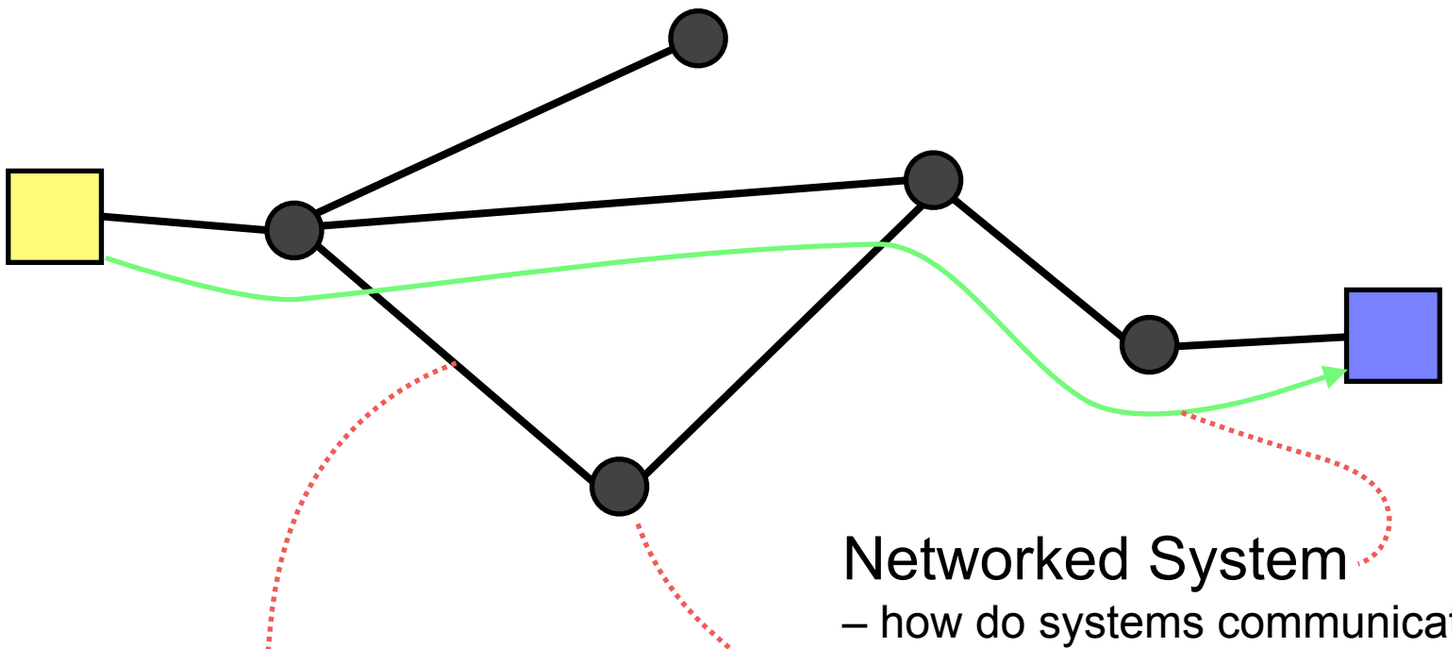
# Introduction to Networked Systems

# Networked Systems

- Autonomous computing devices that exchange data to perform some application goal
  - The exchange of data is explicitly visible to the application – the system is aware of the network
  - Applications using the Internet is one example, but other networks in widespread use:
    - Digital broadcast TV (e.g., FreeView in the UK)
    - Mobile voice telephony
    - Controller area networks connecting sensors and other components within vehicles or aircraft
    - Sensor networks
    - …



# Networked Systems



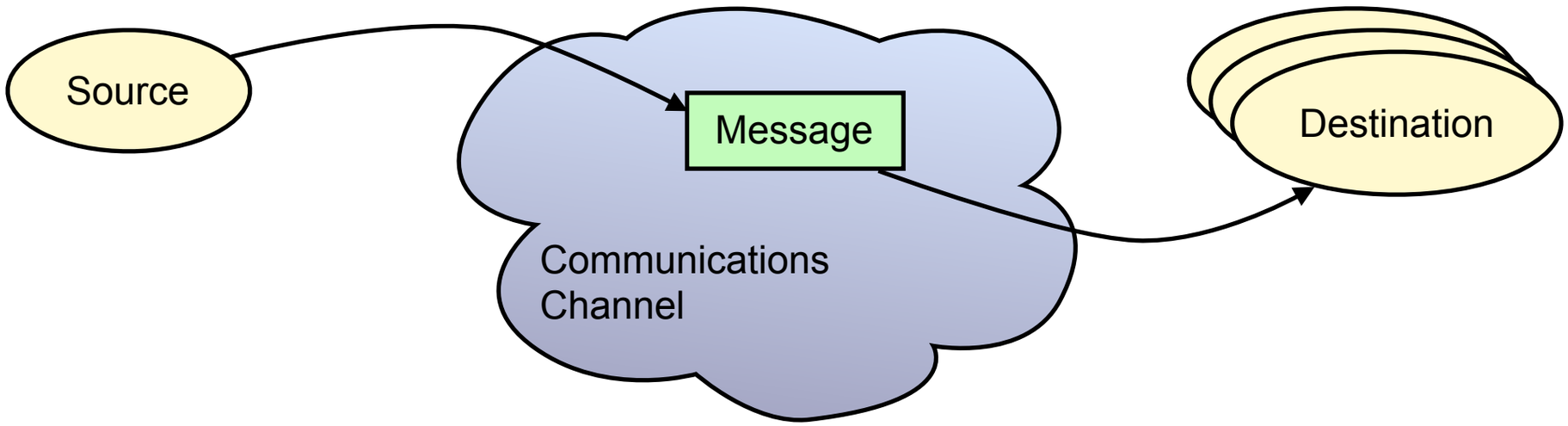
Networked System
– how do systems communicate across the network?

Networking
– how are links interconnected to build a wide-area network?

Communication
– how is information exchanged across a single link?

# Communication

- Messages transferred from source to destination(s) via some communications channel
  - Size of messages might be bounded
  - Communication might be simplex, half- or full-duplex



# Information

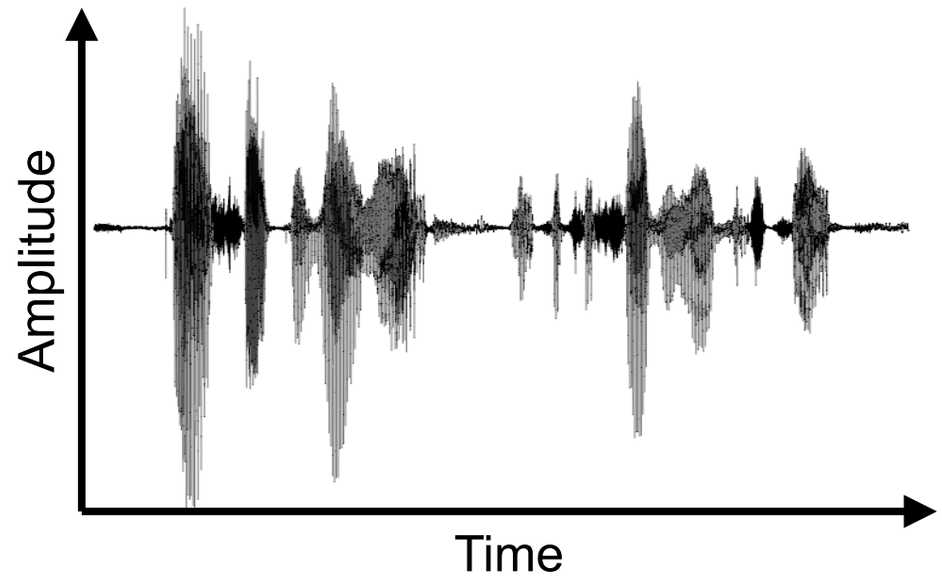
- Messages convey *information*
  - The amount of information in a message can be characterised mathematically – *Information Theory*
- Capacity of channels to convey information can also be modelled
  - How much? How fast? How much power used?
  - Physical limits exist on the capacity of a channel

# Signals

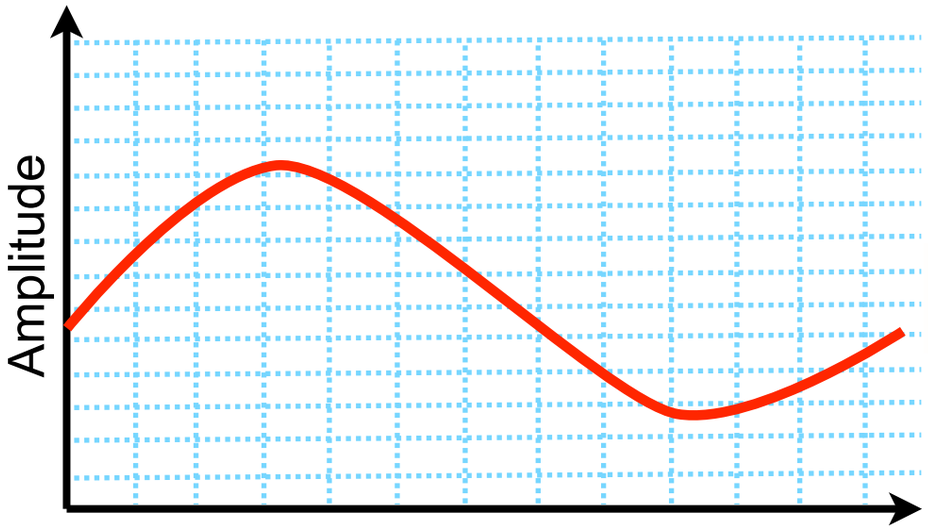
- Physical form of a message is a *signal*
  - May be a material object (carrier pigeon, CD, …)
  - Usually a wave (sound, electrical signal, light, radio, …)
- Signal may be analogue or digital
  - Analogue: a smooth continuum of values
  - Digital: a sequence of discrete *symbols*
    - Mapping information to symbols is known as *coding*

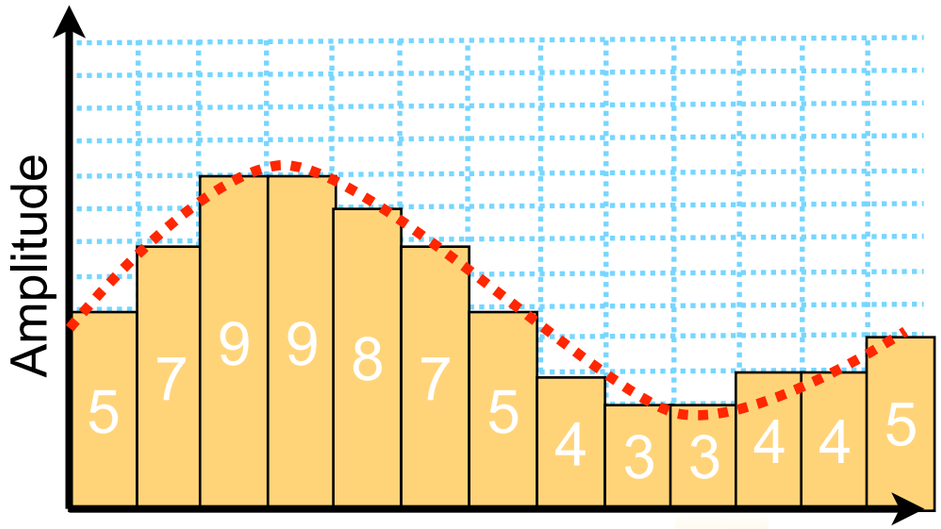
# Analogue Signals

- Simplest analogue signal: amplitude directly codes value of interest
  - AM Radio, analogue telephones
- Can be arbitrarily accurate
- Susceptible to noise and interference on channel
- Difficult to process with digital electronics



# Analogue Signals



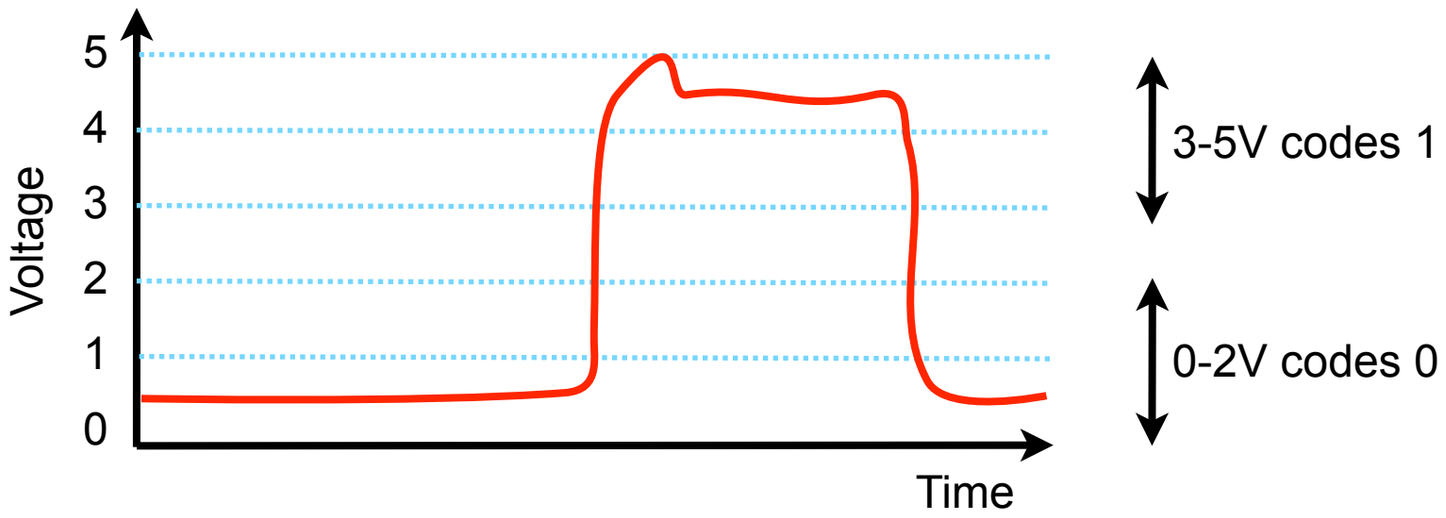

Any analogue signal can be represented digitally: *sample* the signal at a suitable rate, *quantise* to nearest allowable discrete value, and convert to digital representation

- The *sampling theorem* determines the rate at which the signal must be sampled for accurate reconstruction (→ lecture 3)

0101
0111
1001
1001
1000
...

# Digital Signals

- Digital signals comprise a sequence of discrete symbols – fixed alphabet, not arbitrary values
  - But underlying channel is almost always *analogue*
  - Modulation used to map a digital signal onto the channel (→ lecture 3)
- Example: non-return to zero modulation:



# Digital Signals: Baud Rate

- Computing systems use *binary* encoding
  - The digital signal comprises two symbols: 0 and 1
- Networked systems often use non-binary encoding
  - Example: wireless links frequently use *quadrature amplitude modulation* with either 16, 64, or 256 possible symbols (→ lecture 3)
  - Number of symbols transmitted per second is the *baud rate*

Émile Baudot (1845-1903)

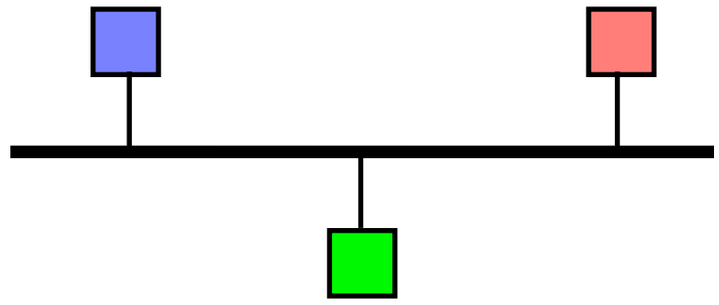
# Channels and Network Links

- A signal is conveyed via a channel
  - May be directly conveyed – electrical signals in a cable
  - May be modulated onto an underlying carrier – radio

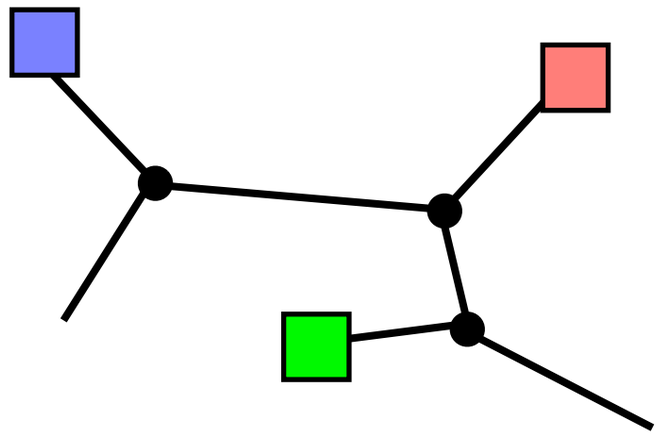
- The combination of signal and channel forms a link

# From Links to Networks

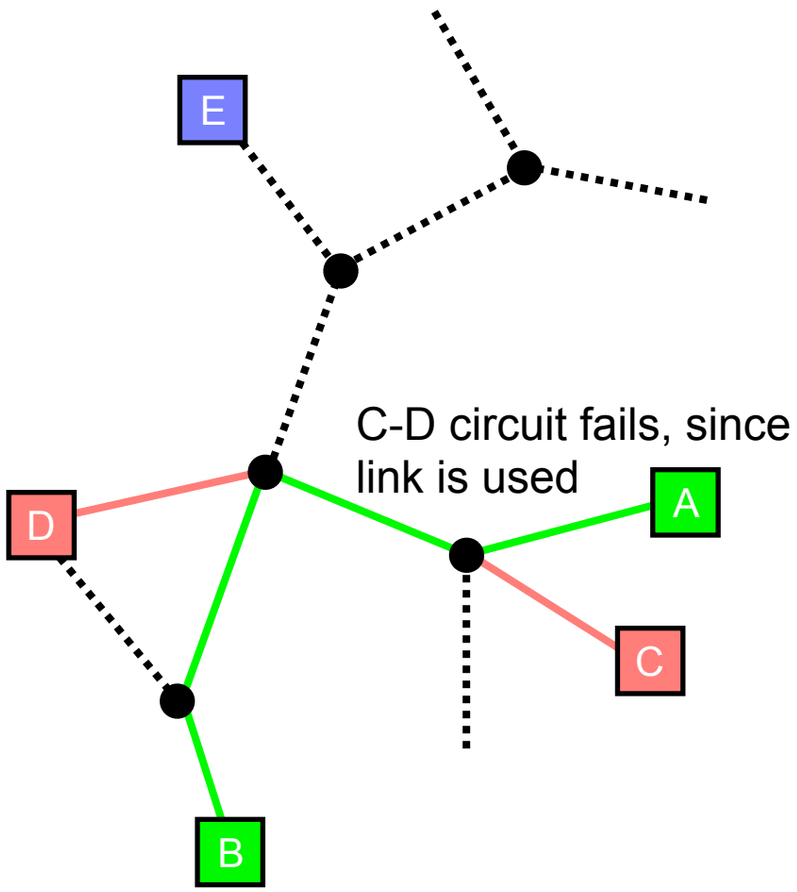
- A link directly connects one or more hosts



- A network comprises several links connected together
- The devices connecting the links are called either *switches* or *routers* depending on the type of network

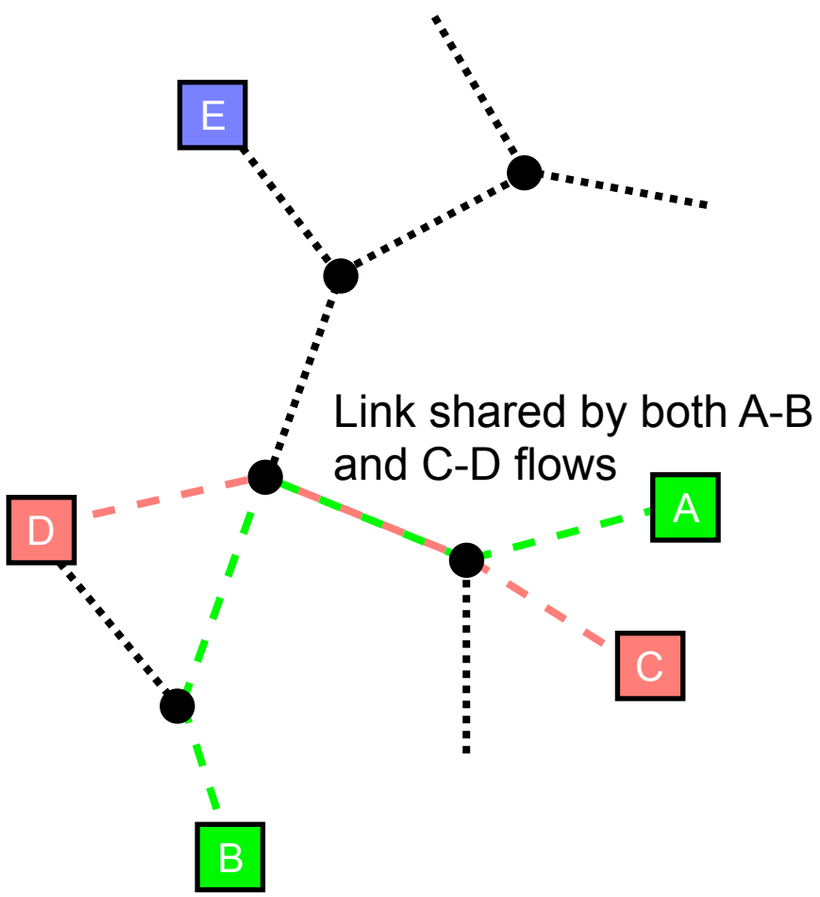


# Circuit Switched Networks




- A dedicated *circuit* can be set up for A and B to communicate
  - A and B exchange arbitrary length messages
  - Guaranteed capacity once circuit is created
  - But – the dedicated circuit can block other communications (e.g. the C to D path); the capacity of the network gives the blocking probability
- Example: traditional telephone network

# Packet Switched Networks




- Alternatively, messages can be split into small *packets* before transmission
  - Allows A-B and C-D to communicate at the same time, sharing the bottleneck link
  - Connectivity guaranteed, but the available capacity varies depending how many other people are using the network
  - Packets are small, and have a size constraint; a message can consist of many packets
  - Example: the Internet

# Networked Systems

- All networked systems built using these basic components:
  - Hosts – the source and destination(s)
  - Links – physical realisation of the channel, conveying messages
  - Switches/routers – connect multiple links
- Layered on top are *network protocols* which give meaning to the messages that are exchanged

# Summary

- Communication → networking → networked systems