University of 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/2015-2016/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
- 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 communication software

Course Outline

Week	Lecture Slot 1	Lecture Slot 2	Laboratory Session
1	Introduction	Protocols and layers	Network programming in C
2	Physical layer	Data link layer	Debug and extend a simple web server
3	Media access control	Bridging	
4	Internetworking	Addressing	
5	Intra-domain routing (1)	Intra-domain routing (2)	A map of (part of) the Internet
6	Inter-domain routing	Transport layer	
7	TCP	Congestion control	
8	UDP	NAT	
9	Transport security	Writing secure code	
10	Higher-layer protocols		

Assessment

- Assessed exercise: 20%
  - One formative exercise: an introduction to network programming in C
  - Two summative exercises (10% each):
    - Debug and extend a simple web server
    - A map of (part of) the Internet
    - *Do not leave the summative exercises until the last minute: they're designed to be completed over several weeks, and are too large to complete in a hurry over a couple of days.*
- Examination: 80%
  - Exam format: answer all three questions

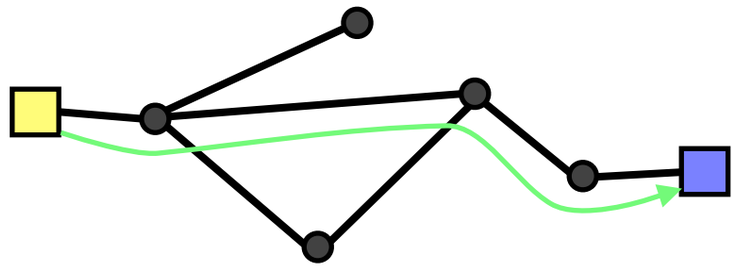
Required Reading

- 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

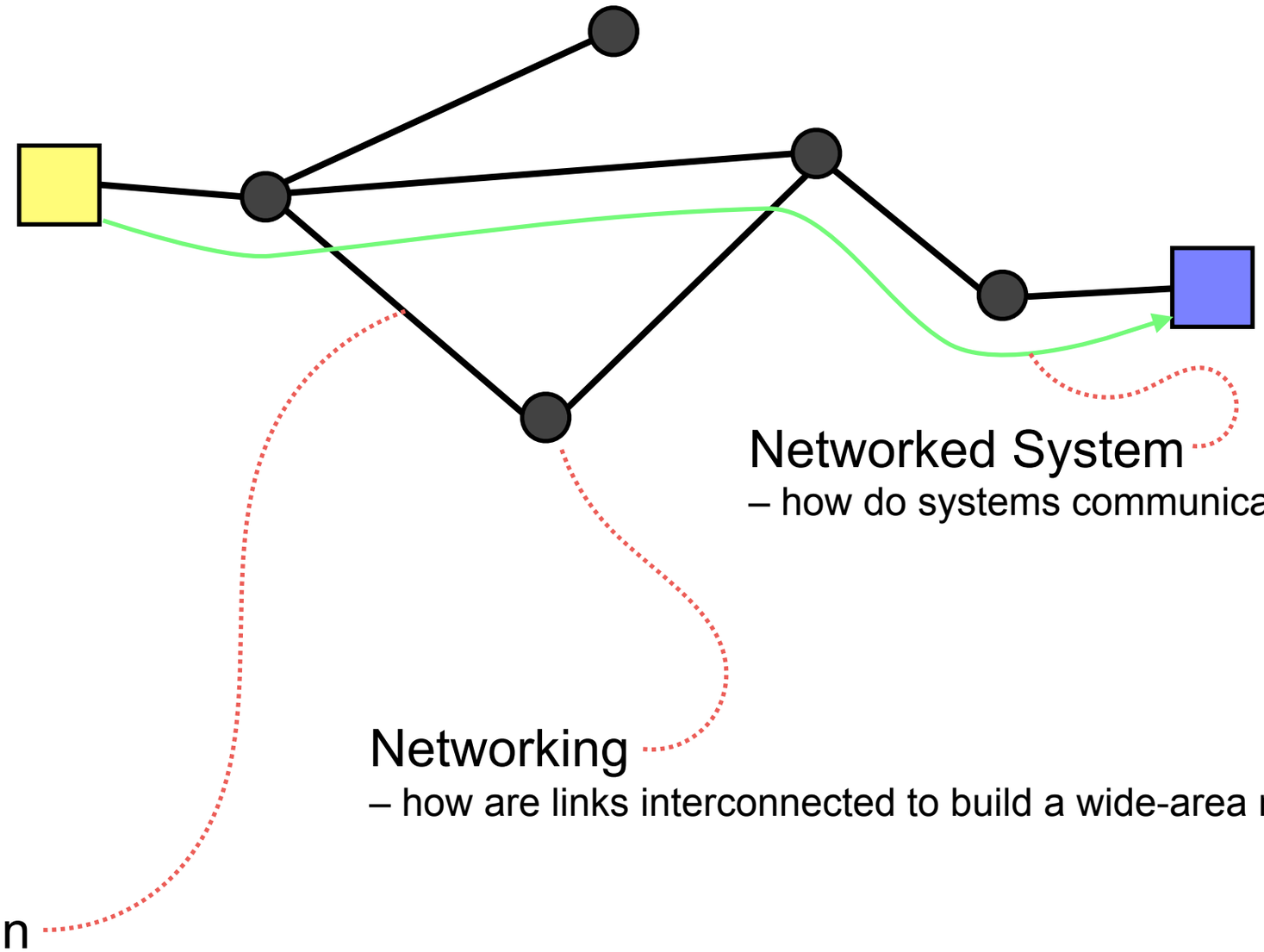
Introduction to Networked Systems

Networked Systems

- Autonomous computing devices which 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

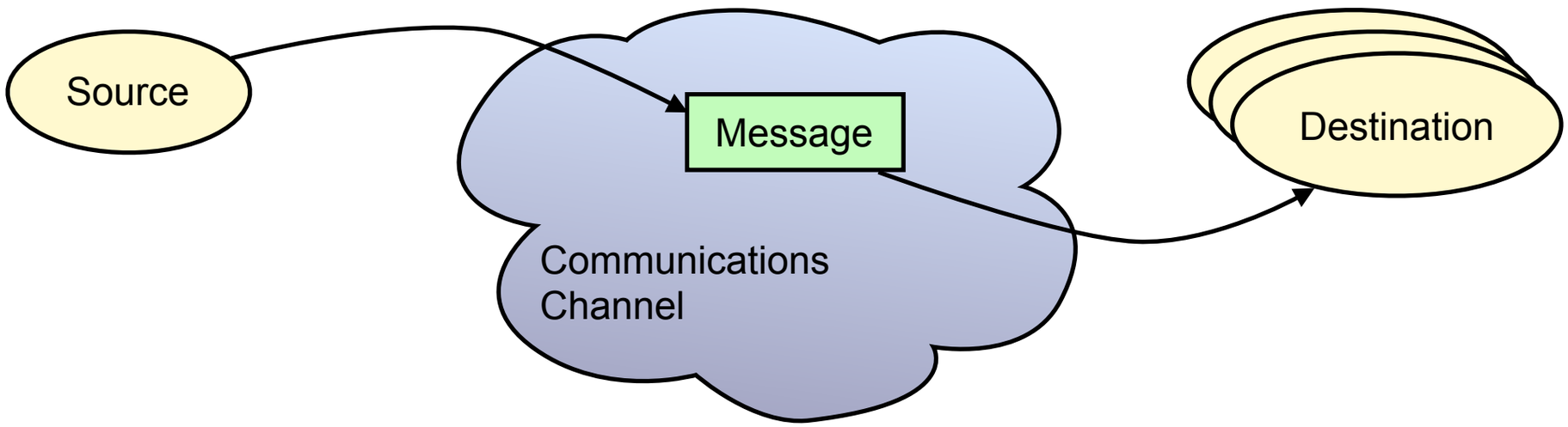


Networked System
– how do systems communicate across the network?

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

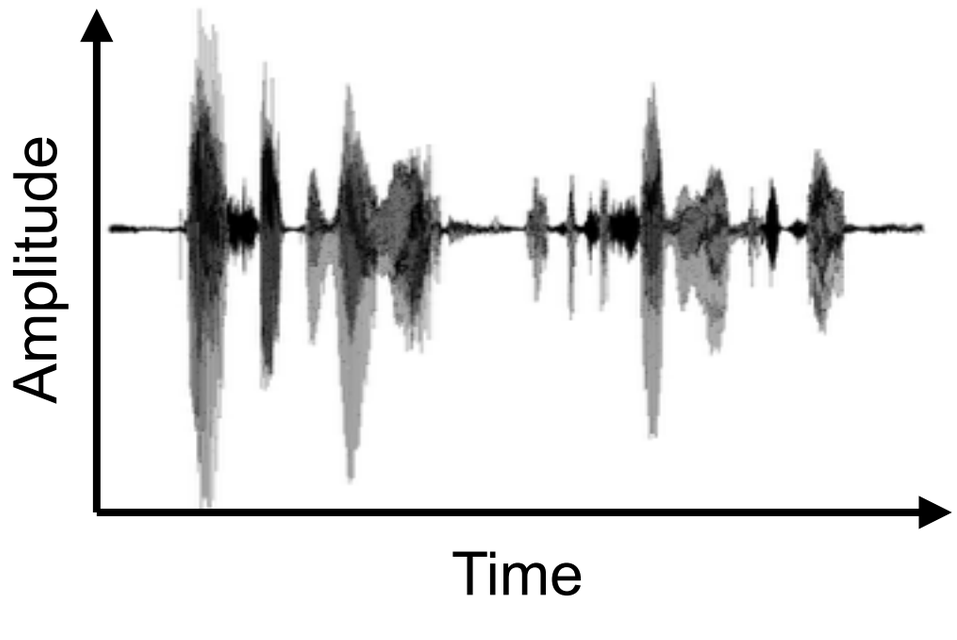
- Messages convey *information*
  - The amount of information in a message can be characterised mathematically – *Information Theory*
- Capacity of channels to convey information can also be modelled
  - How much? How fast? How much power used?
  - Physical limits exist on the capacity of a channel

Signals

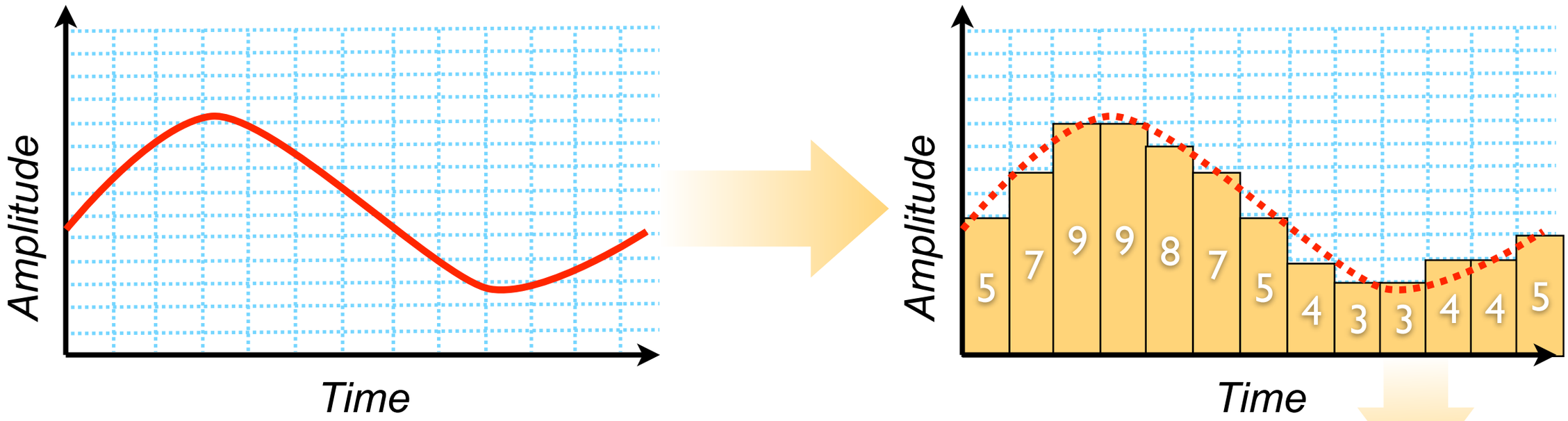
- Physical form of a message is a *signal*
  - May be a material object (carrier pigeon, CD, …)
  - Usually a wave (sound, electrical signal, light, radio, …)
- Signal may be analogue or digital
  - Analogue: a smooth continuum of values
  - Digital: a sequence of discrete *symbols*
    - Mapping information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

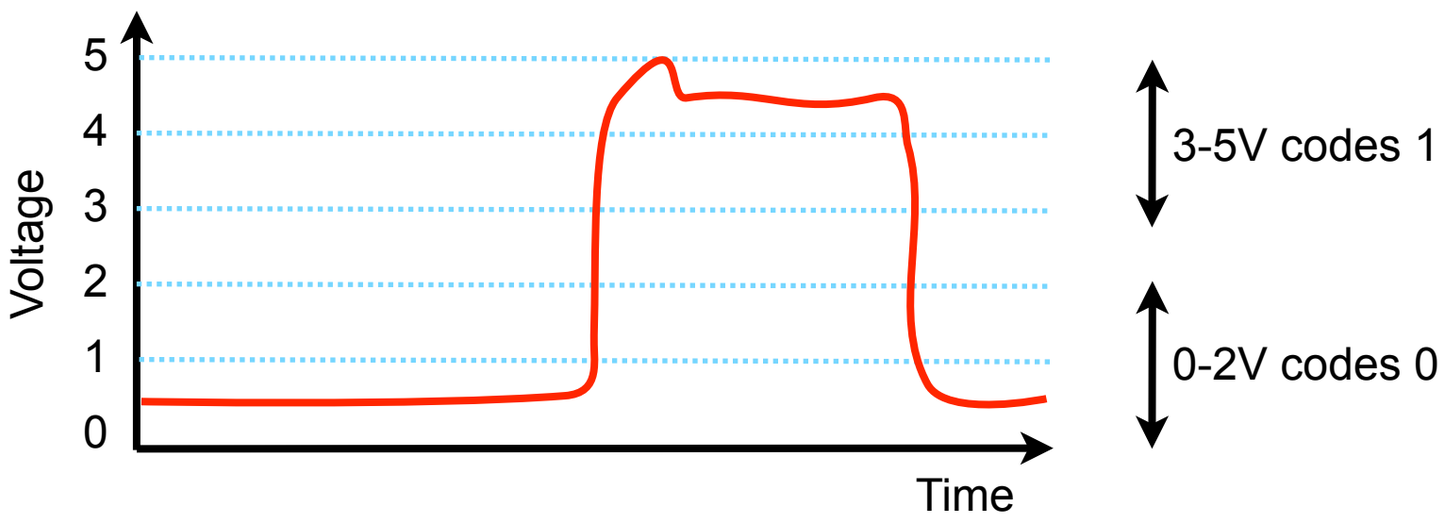
- The *sampling theorem* determines the rate at which the signal must be sampled for accurate reconstruction (→ lecture 3)

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*



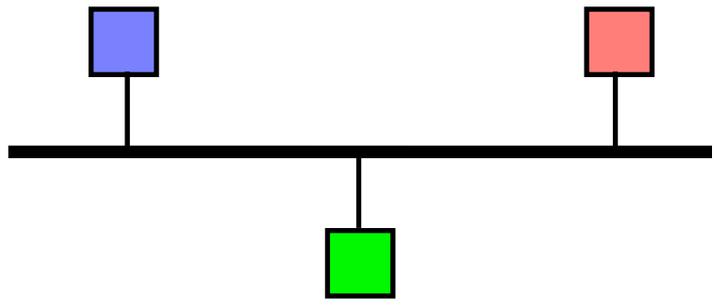
Émile Baudot (1845-1903)

Channels and Network Links

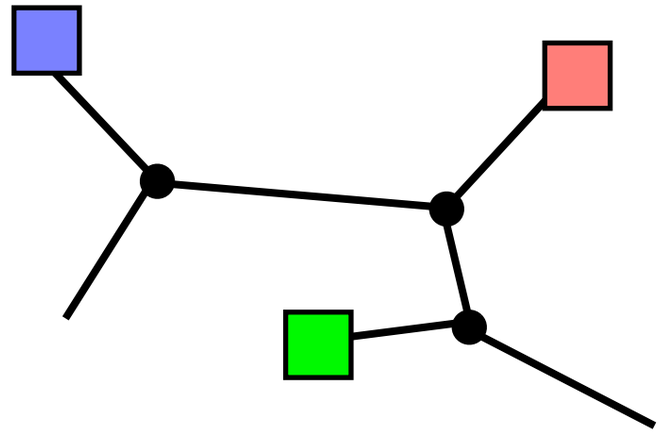
- A signal is conveyed via a channel
  - May be directly conveyed – electrical signals in a cable
  - May be modulated onto an underlying carrier – radio
- The combination of signal and channel forms a link

From Links to Networks

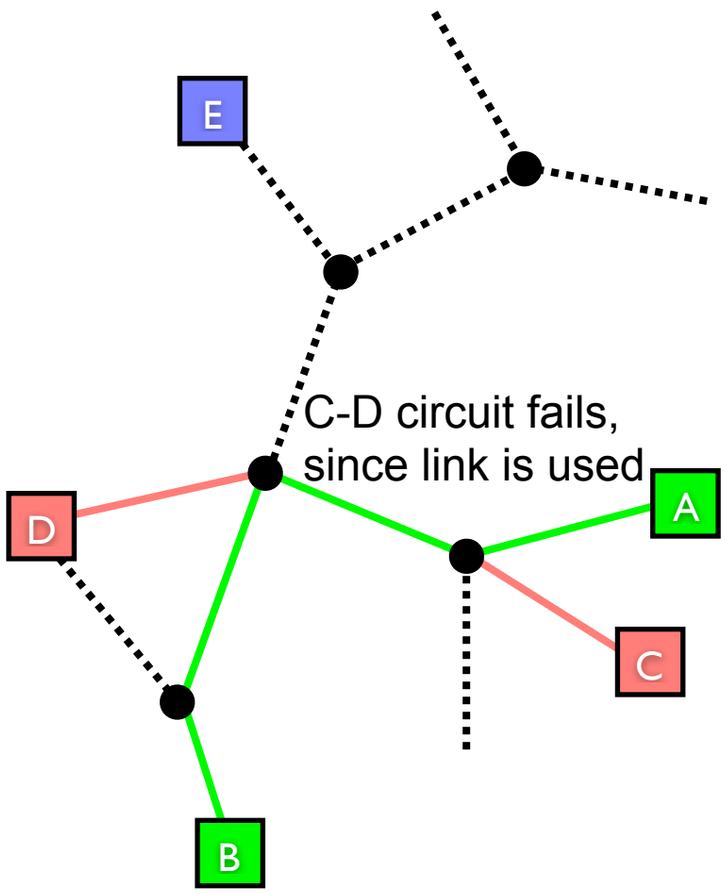
- A link directly connects one or more hosts



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

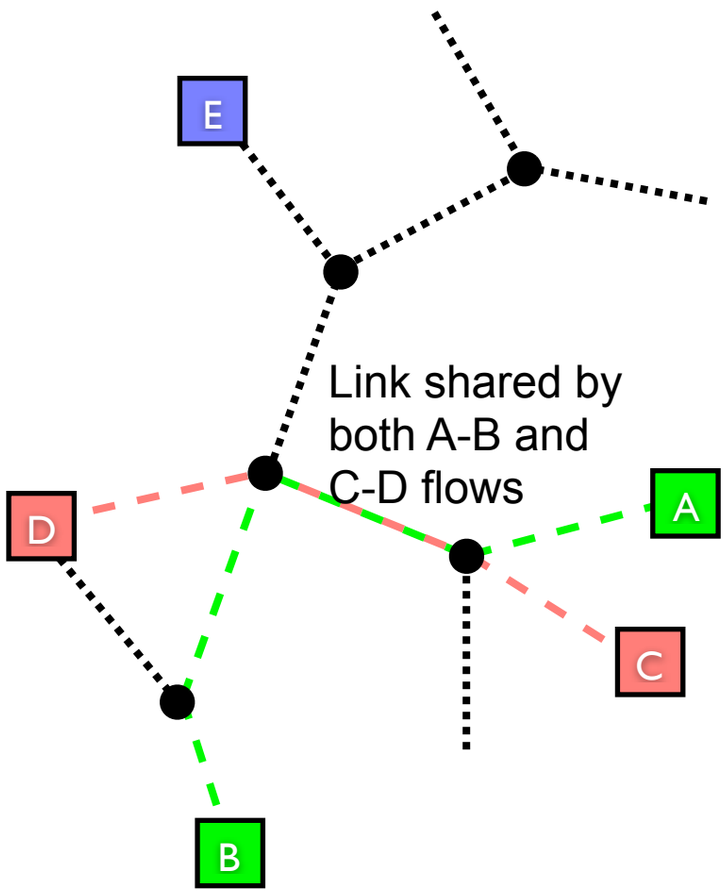


Circuit Switched Networks



- 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