Protocols and Layers

Networked Systems 3
Lecture 2

Lecture Outline

- Network Protocols
  - Syntax and semantics
- Protocol Layering
  - OSI Reference Model
- Protocol Standards

Network Protocols

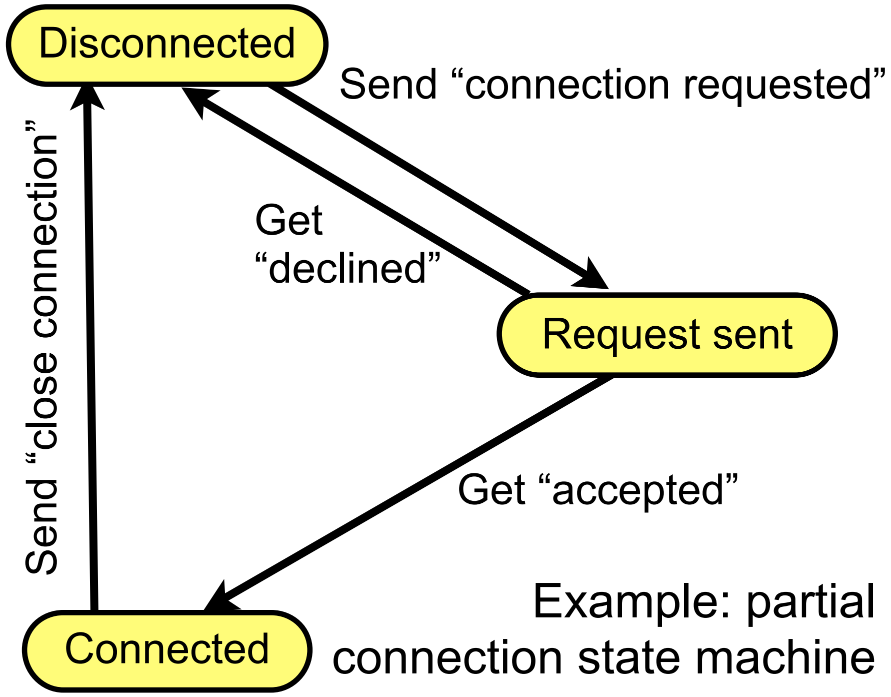
- Communication occurs when two (or more) hosts exchange messages across a network
- To be meaningful, the messages need follow some well known *syntax*, and have agreed *semantics*
  - A *network protocol* is an agreed language for encoding messages, along with the rules defining what messages mean and when they can be sent
    - c.f. a programming language, where syntax and semantics define the legal programs
  - Numerous network protocols exist; some operate between hosts, some between routers, and some between hosts and routers
  - The protocols define the behaviour of the network

Network Protocols: Syntax

- A protocol will comprise different types of message
  - Known as *protocol data units* (PDUs)
- Each type of PDU will have a particular syntax
  - Describes what information is included in the PDU, and how it’s formatted
  - PDUs may be formatted as textual information or as binary data
    - Textual PDUs have a syntax and grammar that describes their format
      - Much like a programming language has a grammar
      - Examples: HTTP/1.1, SMTP, SIP, Jabber
    - Binary PDUs similarly have rules describing their format
      - Is data big or little endian? 32 or 64 bit? Fixed or variable length? What are the alignment requirements?
      - Examples: TCP/IP, RTP
- PDUs define what messages are legal to send

Network Protocol: Semantics

- Protocol semantics define when PDUs can be sent, and what response is needed
  - Define who can send PDUs, and when they can be sent
  - Define roles for the hosts (e.g., client and server, peer-to-peer)
  - Define what are the entities that communicate and how they are named
  - Define how errors are handled
- Commonly described using state-transition diagram
  - States indicate stages of protocol operation
  - Transitions occur in response to PDUs, and may result in other PDUs being sent



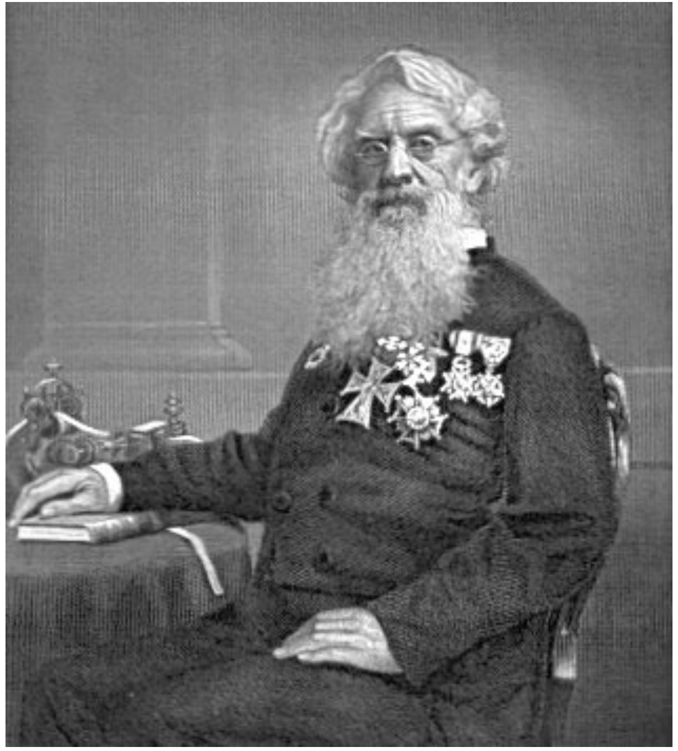
Example: partial connection state machine

Network Protocol Example: Morse Code

- A simple network protocol: Morse code and the telegraph
  - Signals on electrical cable form the channel
  - Protocol syntax: pattern of dots and dashes signals letters

A	•-	J	•---	S	•••
B	-•••	K	-•-	T	-
C	-•-•	L	•-••	U	••-
D	-••	M	--	V	•••-
E	•	N	-•	W	•--
F	••-•	O	---	X	-••-
G	--•	P	•--•	Y	-•--
H	••••	Q	--•-	Z	--••
I	••	R	•-•		

  - Protocol semantics:
    - Different gap lengths to signal end of word, end of latter
    - Use of STOP for end of message

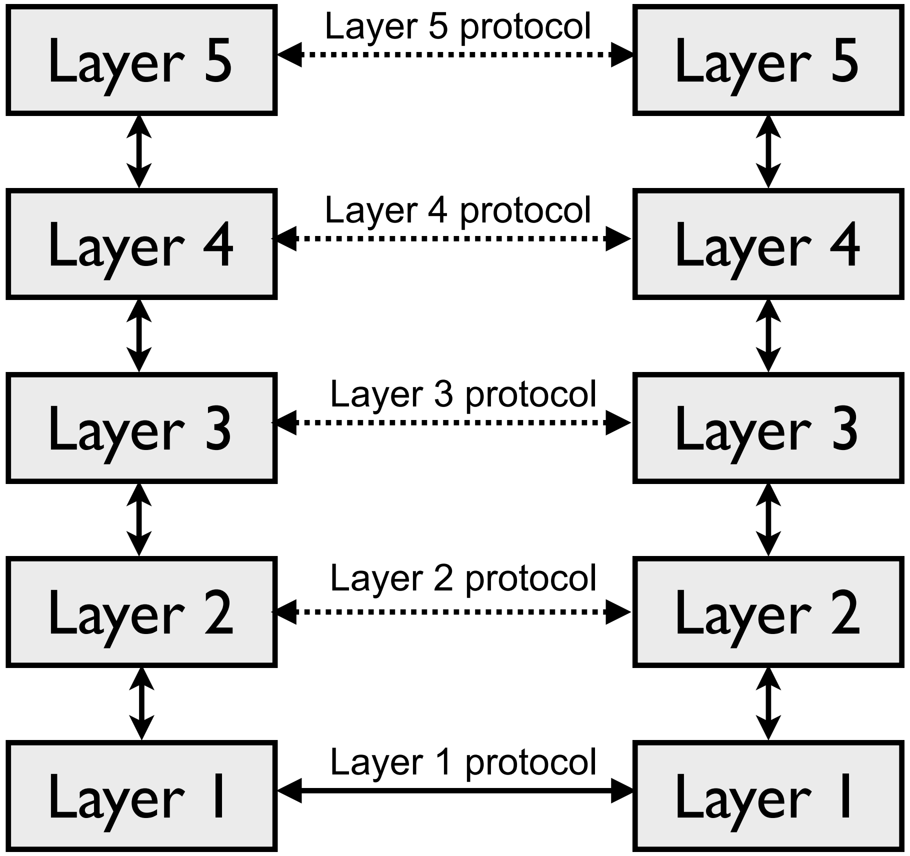


Samuel Morse

Photos: public domain (source Wikipedia)

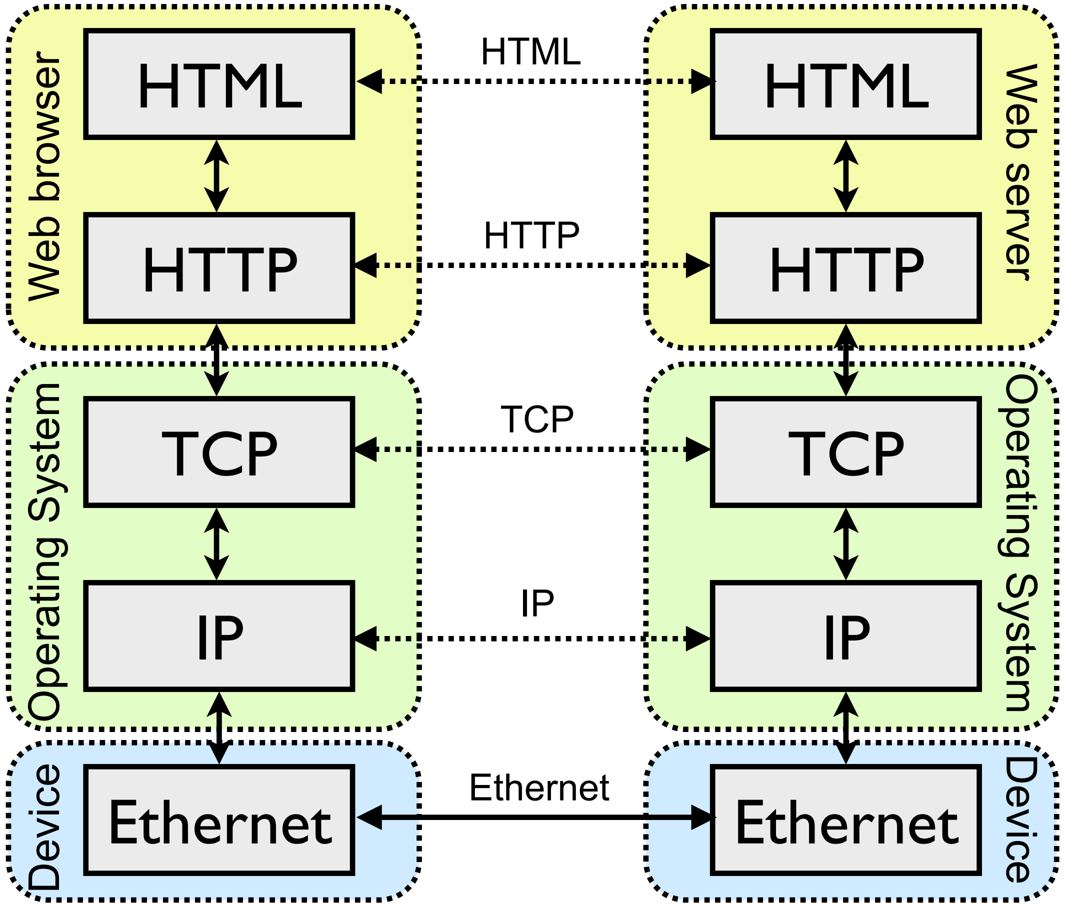
Protocol Layering

- Communications systems are typically organised as a series of *protocol layers*
  - Structured design to reduce complexity
  - Each layer offers *services* to the next higher layer, which it implements using the services of the lower layer – well defined *interfaces*
    - Highest layer is the communicating application
    - Lowest layer is the physical communications channel
  - Peers at some layer, *i*, communicate via a layer *i* protocol, using lower layer services



Protocol Layering: Example

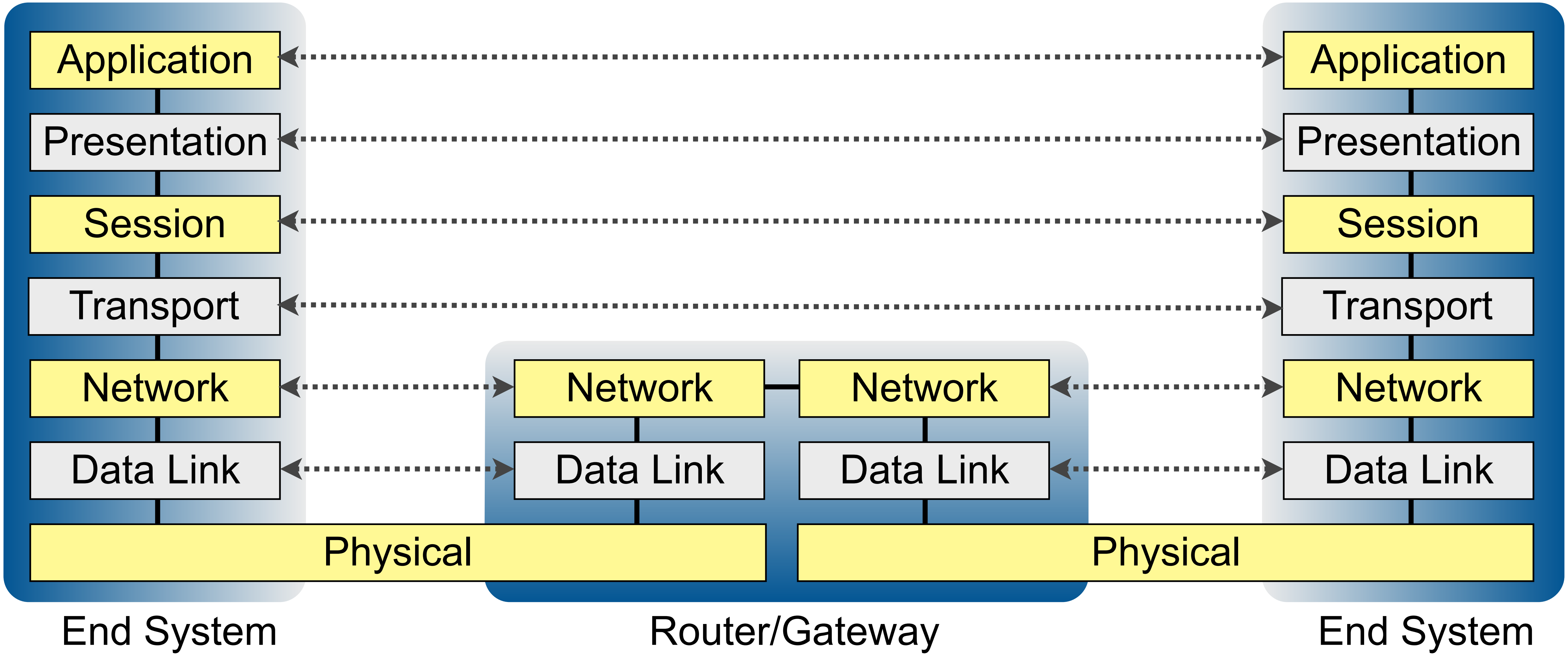
- Web browser talking to a web server
- Simplified view with five protocol layers:
  - HTML
  - HTTP
  - TCP
  - IP
  - Ethernet



OSI Reference Model

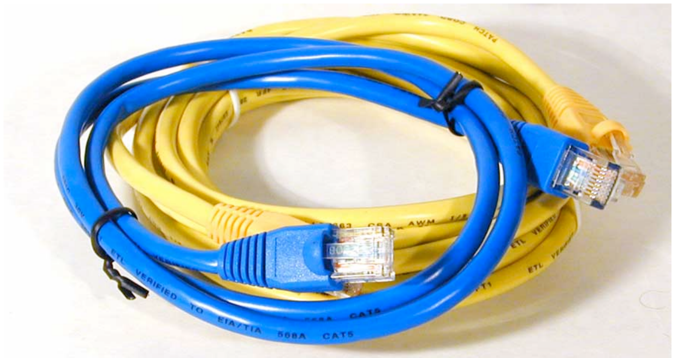
A standard way of thinking about layered protocol design

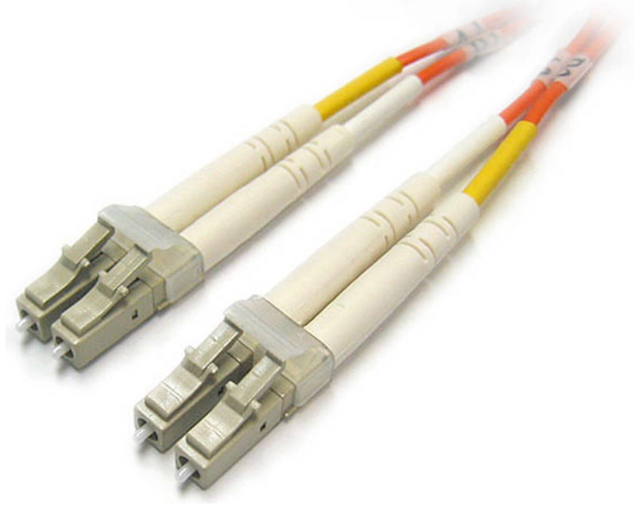
A design tool; real implementations are more complex



Physical Layer

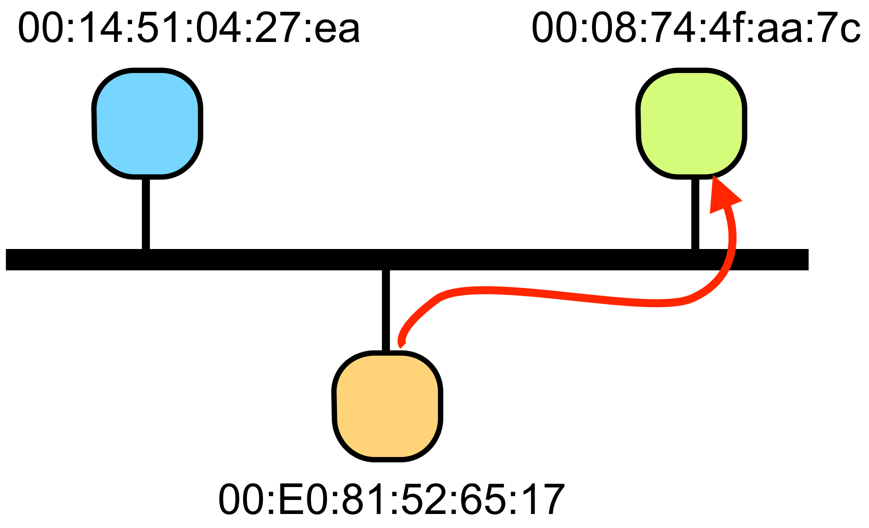
- Defines characteristics of the cable or optical fibre used:
  - Size and shape of the plugs
  - Maximum cable/fibre length
  - Type of cable: electrical voltage, current, modulation
  - Type of fibre: single- or multi-mode, optical clarity, colour, power output, and modulation of the laser
- For wireless links:
  - Radio frequency, transmission power, modulation scheme, type of antenna, etc.





Data Link Layer

- Structure and frame physical layer bit stream
  - Split the bit stream into messages
  - Detect/correct errors in messages
    - Parity and error correcting codes
    - (Negative) acknowledgements + retransmission
- Perform media access control
  - Assign addresses to hosts on the link
  - Arbitrate access to link, and determine when hosts are allowed to send message
  - Ensure fair access to the link and provide flow control to avoid overwhelming hosts
- Examples: Ethernet, 802.11



Network Layer

- Interconnects multiple links to form a wide area network from source host to destination host
  - Data delivery
  - Naming and addressing
  - Routing
  - Admission/Flow control
- Example: IP

Transport Layer

- End-to-end transfer of data from the source to the destination(s)
    - Transfers data between a session level service at the source, and corresponding service at the destination
    - May provide reliability, ordering, framing, congestion control, etc.
        - Depends on guarantees provided by the network layer
- Example: TCP

Session Layer

- Manages (multiple) transport layer connections
- Example session layer functions:
  - Open several TCP/IP connections to download a web page using HTTP
  - Use SMTP to transfer several email messages over a single TCP/IP connection
  - Coordinate control, audio and video flows making up a video conference

Presentation Layer

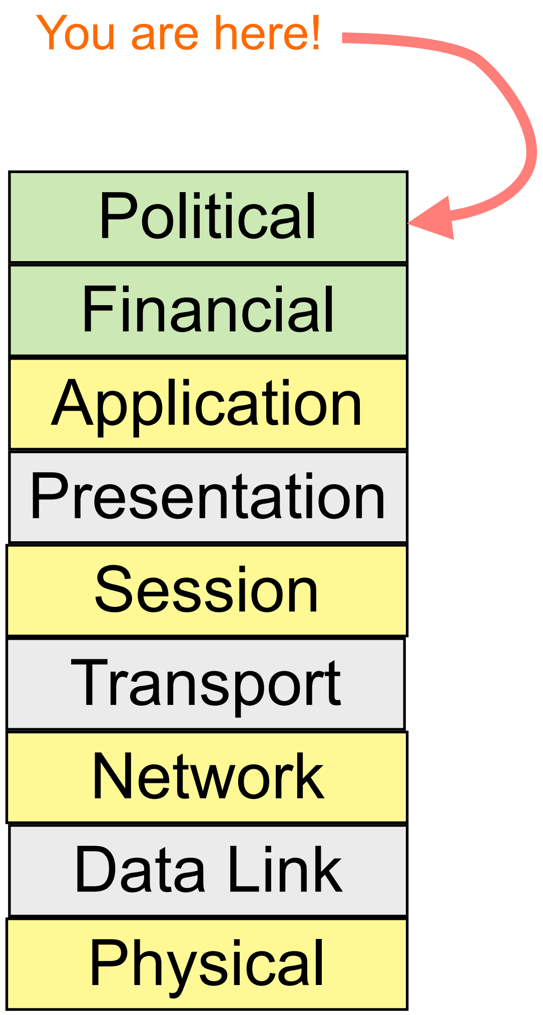
- Manages the presentation, representation, and conversion of data:
  - Character set, language, etc.
  - Data markup languages (e.g. XML, HTML)
  - Data format conversion (e.g. big or little endian)
  - Content negotiation (e.g. MIME, SDP)
- Common services used by many applications

Application Layer

- User application protocols
  - *Not* the application programs themselves
- Examples:
  - Flickr API, Facebook API, Google Maps API, etc.
  - Web services
  - Grid computing

Protocol Standards

- A formal description of a network protocol
- Ensure interoperability amongst diverse implementations
- Variety of standards setting procedures:
  - Open or closed standards development process
  - Free or restricted standards availability
  - Individual vs. corporate vs. national membership
  - Lead technical development or document existing practice



Key Standards Organisations

- Internet Engineering Task Force
    - http://www.ietf.org/ and http://www.rfc-editor.org/
- International Telecommunications Union
    - http://www.itu.int/ (part of the United Nations)
- 3rd Generation Partnership Project
    - http://www.3gpp.org/
- World Wide Web Consortium
    - http://www.org/

Summary

- Protocols: syntax and semantics
- Layered network architectures
- Importance of standards

“Networks are like onions…”