Networks & Operating Systems Essentials

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School of Computing Science, Room: S122

Today, on NOSE2…

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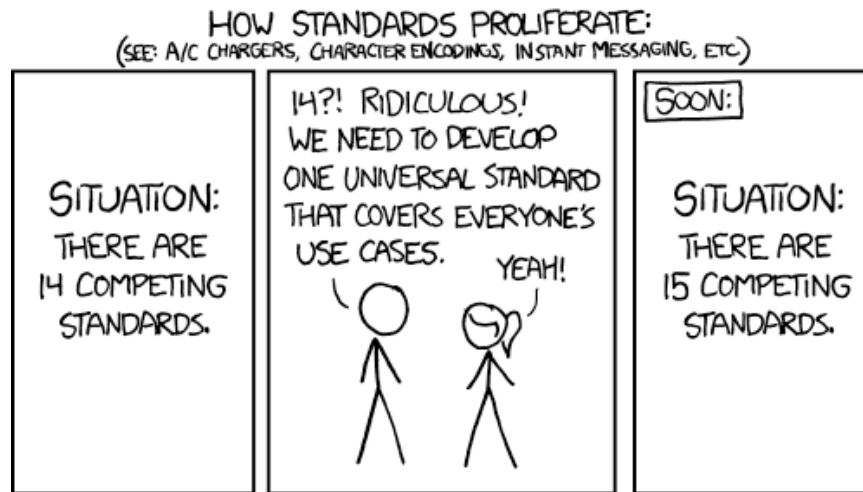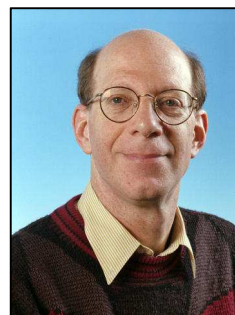
The nice thing about standards is that you have so many to choose from.

(Andrew S. Tanenbaum)

Image source: http://www.linux-magazine.com/Online/News/Why-Can-t-Computers-Just-Work-All-the-Time

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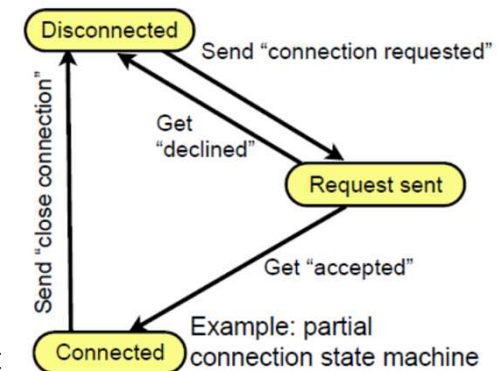
PROTOCOLS & LAYERS

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

- 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

- 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

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Network Protocols

- A simple network protocol: Morse code and the telegraph
  - Signals on electrical cable form the channel
  - 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	· · ·		

  - Semantics:
    - Different gap lengths to signal end of word, end of letter
    - Use of STOP for end of message

Samuel Morse
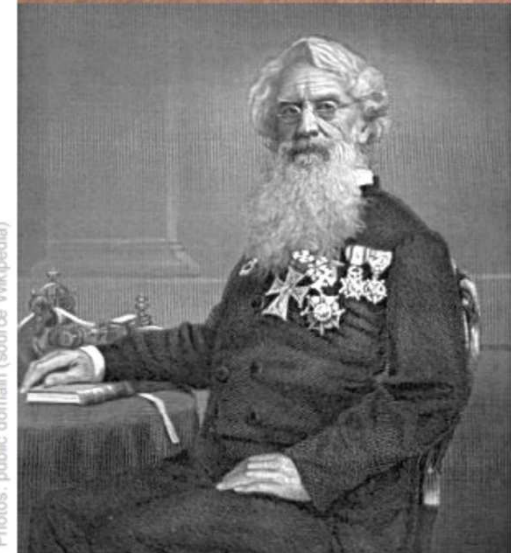
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Protocol Layering

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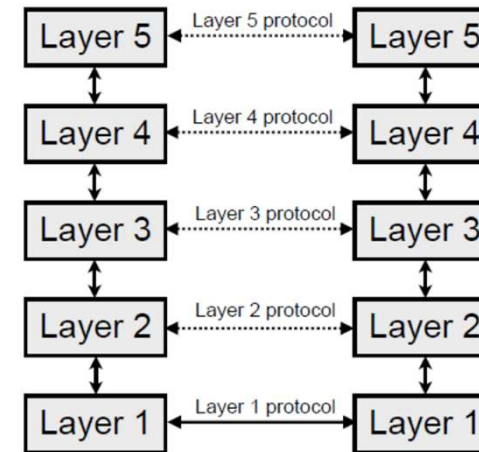
- Example: web browser talking to a web server
  - Simplified view with five protocol layers
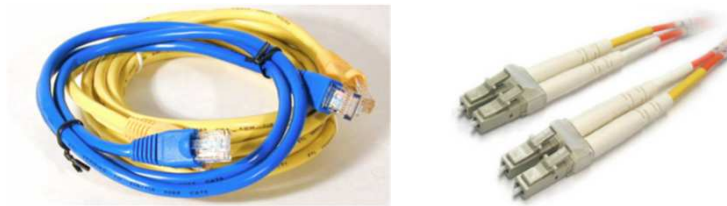   - HTML
    - HTTP
    - TCP
    - IP
    - Ethernet

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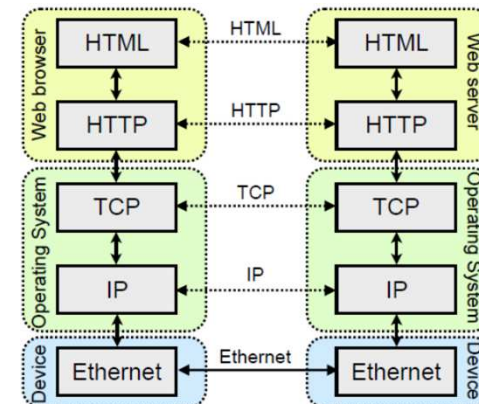
OSI Reference Model

- A standard way of thinking about layered protocol design
- A design tool; real implementations are more complex
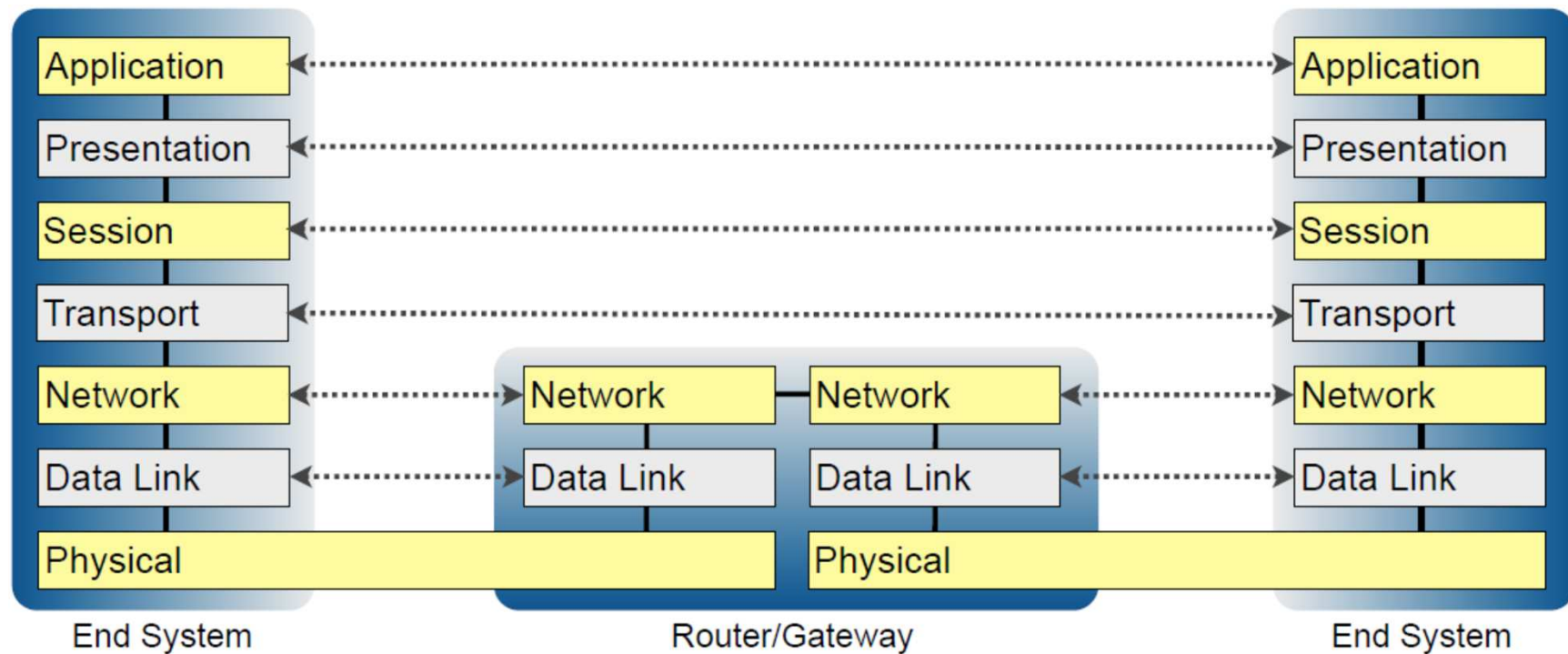
Physical Layer

- 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.

OSI Model

data unit	layers	
data	application	Network Process to Application
data	presentation	Data Representation & Encryption
data	session	Interhost Communication
segments	transport	End-to-End Connections and Reliability
packets	network	Path Determination & Logical Addressing (IP)
frames	data link	Physical Addressing (MAC & LLC)
bits	physical	Media, Signal and Binary Transmission

Host Layers / Media Layers

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

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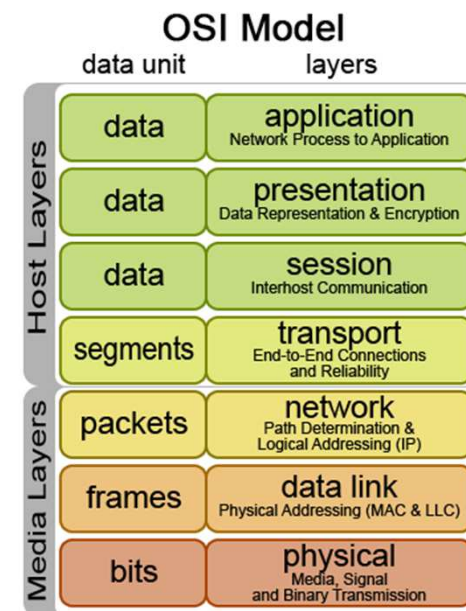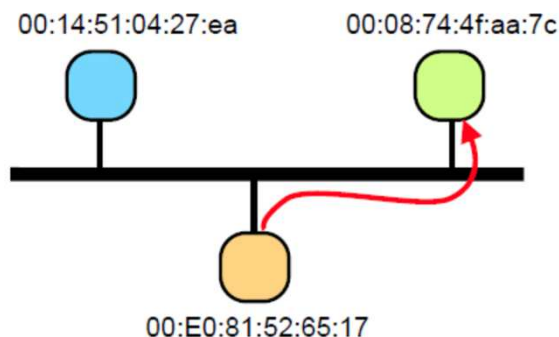
Network Layer

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

OSI Model

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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

- Examples: TCP, UDP
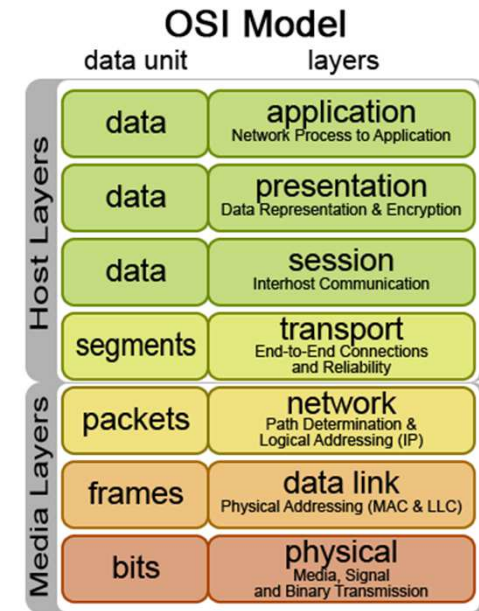
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Host Layers: application, presentation, session, transport

Media Layers: network, data link, physical

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

OSI Model

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Host Layers: application, presentation, session, transport
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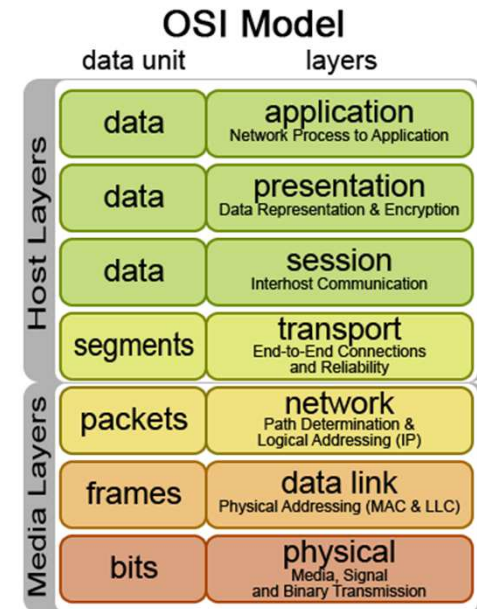University of Glasgow | School of Computing Science

Presentation Layer

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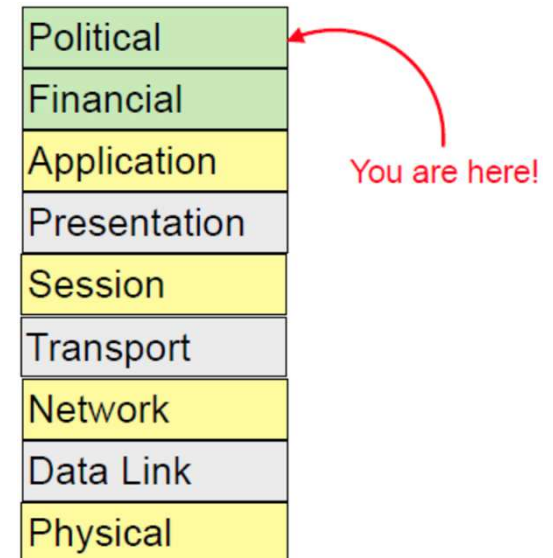- Common services used by many applications
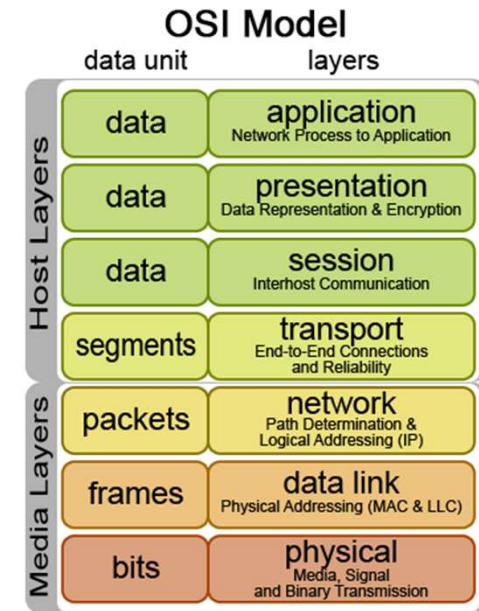
Application Layer

- User application protocols
  - Not the application programs themselves

- Examples:
  - REST APIs
  - WebRTC

OSI Model

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Protocol Standards

- A formal description of a network protocol
- Ensure interoperability of diverse implementations
- Variety of standards setting procedures:
  - Open or closed standards development process
  - Free or restricted standards availability
  - Rules around disclosure of intellectual property rights, use of encumbered technologies
  - Individual vs. corporate vs. national membership
  - Lead technical development vs. describe existing practices
  - Collaborative vs. combative process

- Not all players in the standards process have the same goals
  - Delaying a standard to allow a proprietary solution to gain market share
  - Incorporating intellectual property, patented technologies, etc.
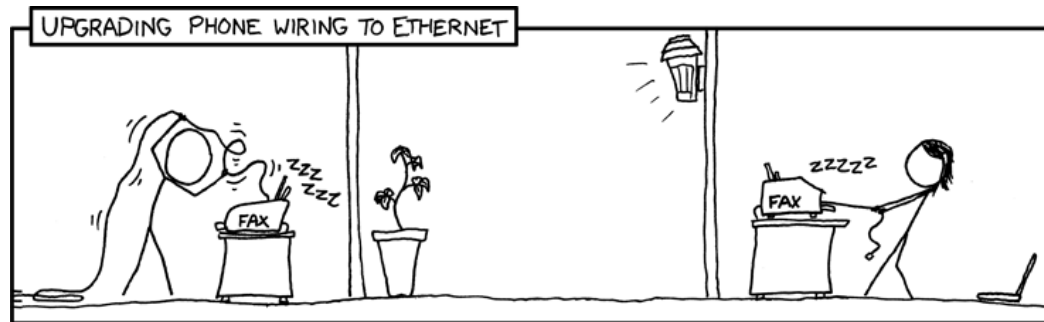 - Enhancing, or subverting, the security of a protocol
  - …

Political
Financial
Application
Presentation
Session
Transport
Network
Data Link
Physical

You are here!

Key Standards Organisations

- Internet Engineering Task Force
  - http://www.ietf.org/
  - 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/

Coming up next…

Source: https://xkcd.com/454/

Source: https://xkcd.com/466/