Protocol Layering & Cross Layer Design

EE3204: Computer Communication Networks I

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Outline

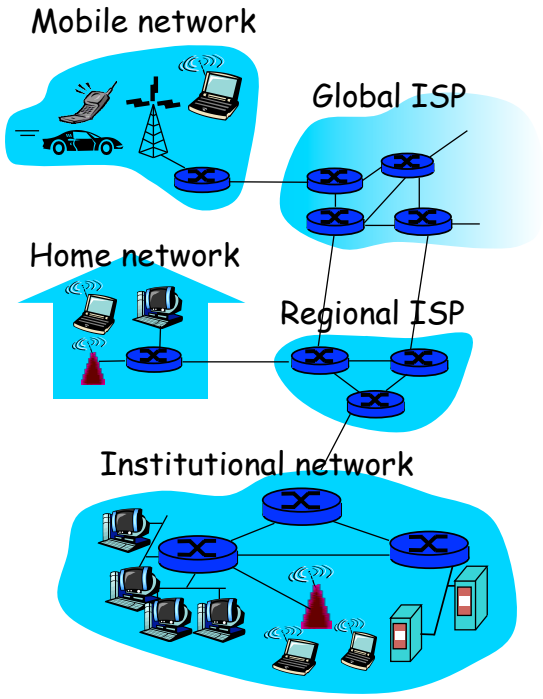
- A look inside the Network
- What is Layering?
- The OSI model and its seven layers
- TCP/IP Model
- Cross Layer Design
- Putting it all together

Note: Some slides & graphics adapted from:

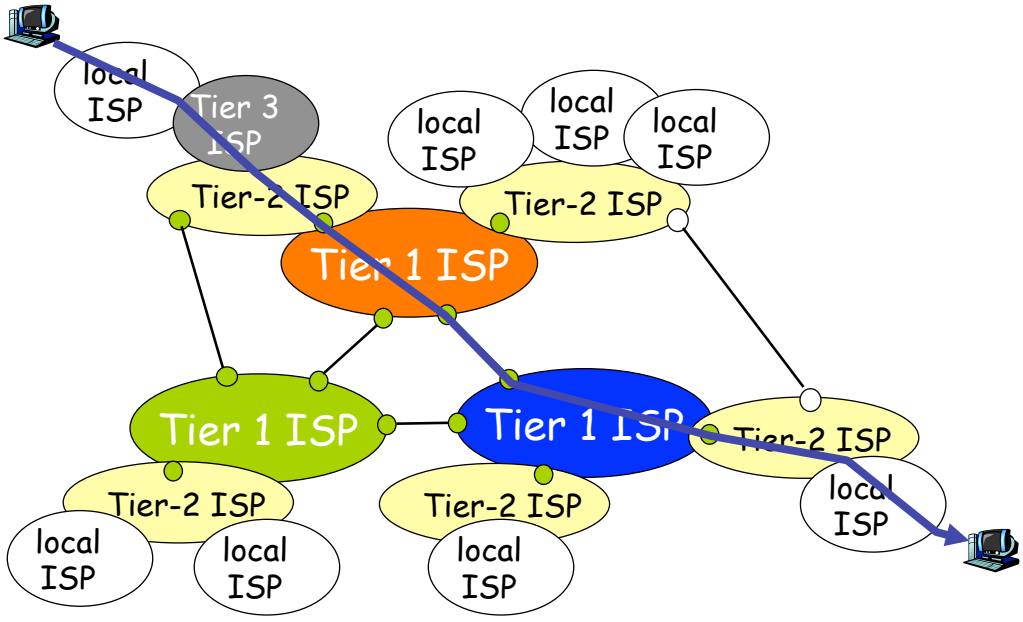
- Vineet Srivastava, Cross-layer Design, Master's Thesis, NUS.
- Kurose & Ross, Computer Networking

A look inside a computer network

- Millions of connected computing devices running network apps
- Communication links - fiber, copper, radio, satellite
- Routers & Base Stations - route and forward data
- Protocols control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, Ethernet
  - E.g., GSM, GPRS, 3G, 4G
- Internet standards
- RFC: Request for comments
- IETF: Internet Engineering Task Force

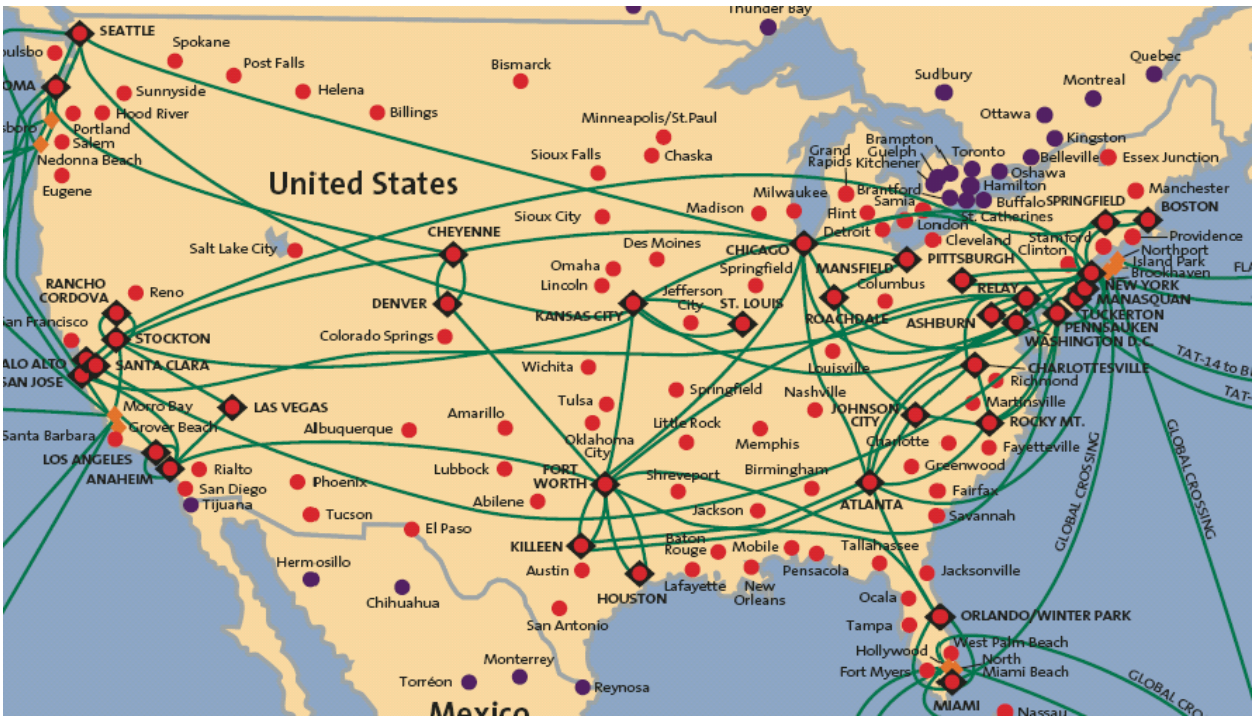


Internet: network of networks ...



➢ a packet passes through many networks!

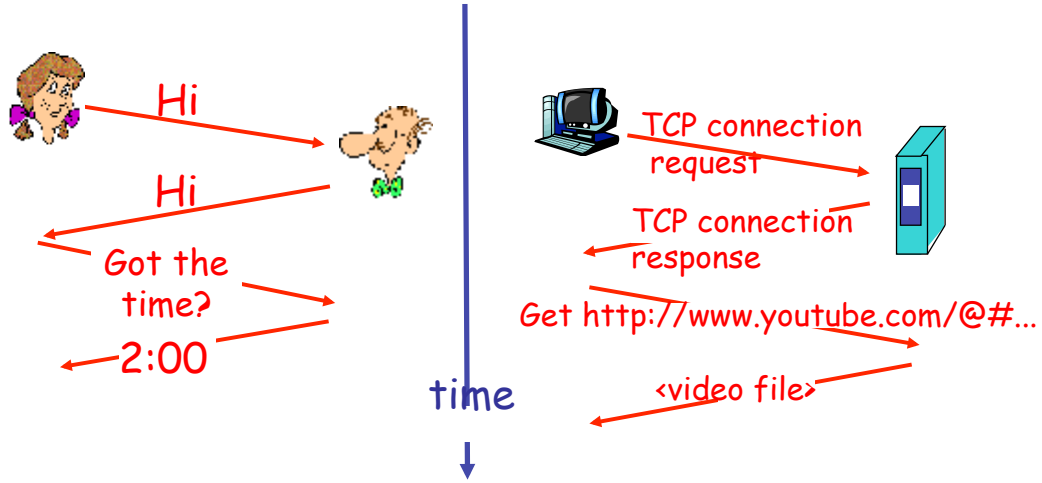
Sprint backbone (USA Tier-1 ISP)



Singtel regional network

What's a protocol?

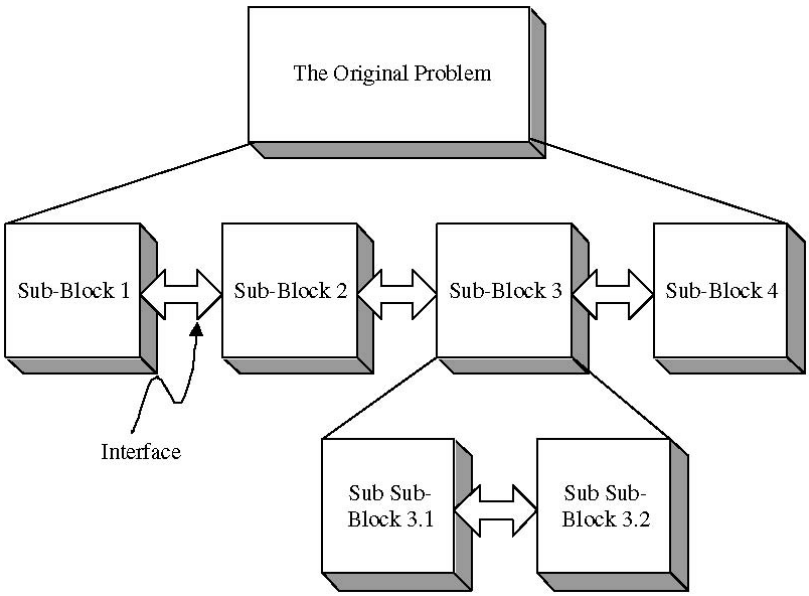
- Defines acceptable behaviour
- Agreed data format: Handshake, Message, Response



Q: Can you think of other protocols?

Protocol layering – Divide and Conquer

Question: How do we organize a complex network to make it more manageable?



Layering – Sending a letter to a friend

Hand Deliver

- Write the letter
- Travel to your friend's house and hand deliver letter.

Use the Post Office

- Write the letter
- Address, Stamp, and Put in mailbox
- Postman collects and brings to local post office
- Post office routes letter to remote post office
- Postman delivers letter to your friend

Why layering?

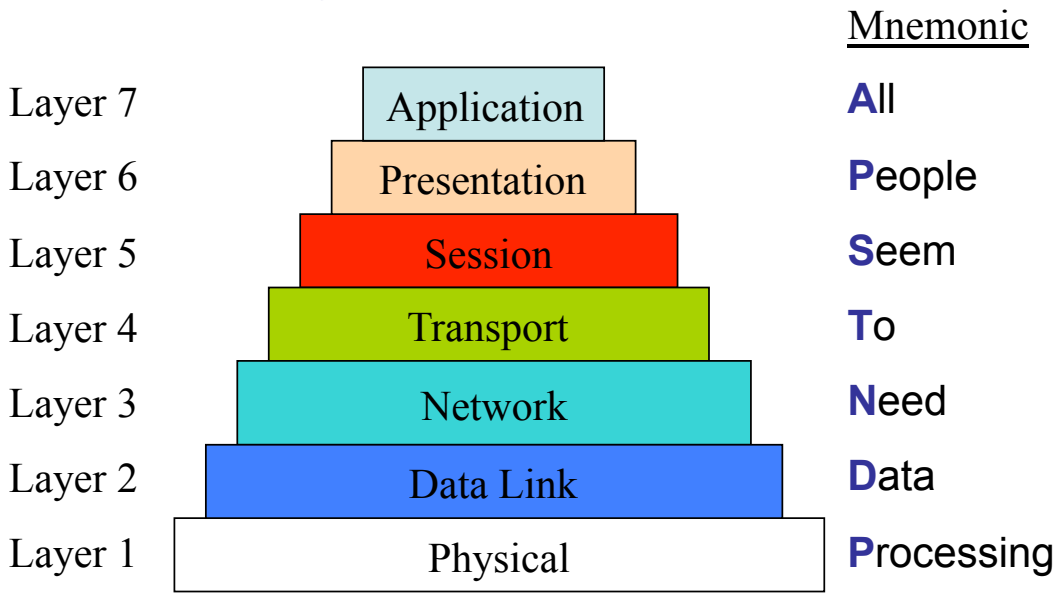
Dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
- Can layering be considered harmful?

The OSI Model

- **Open Systems Interconnection –** a reference model for all communications between network devices.
- Networks built using different hardware and software implementations are incompatible.
- The International Organisation for Standardisation (ISO) created a network model that would help vendors create interoperable network implementations → the OSI model

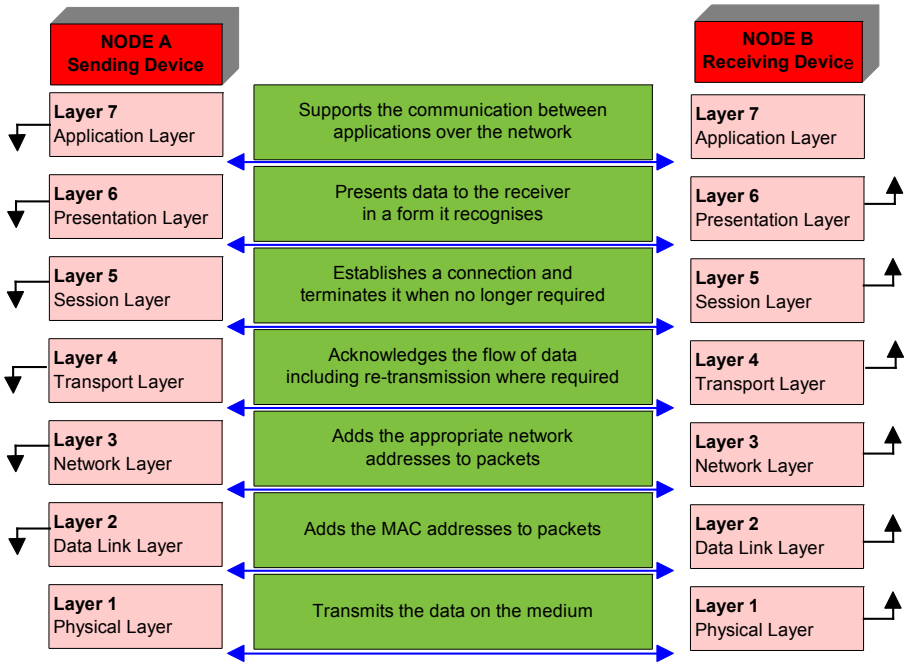
Seven Layers of the OSI



The Layers at Work

- Each layer is separate, independent and has its own function
- Each layer provides a service to those layers above and below itself
- When communicating, each OSI layer talks with the same layer in the other device
  - Example: Application Layer of Device A communicates with the Application Layer of Device B, by passing the data through the other layers
- Each Layer of each device is not concerned with how the other layers are functioning, but it does rely on them to do their job

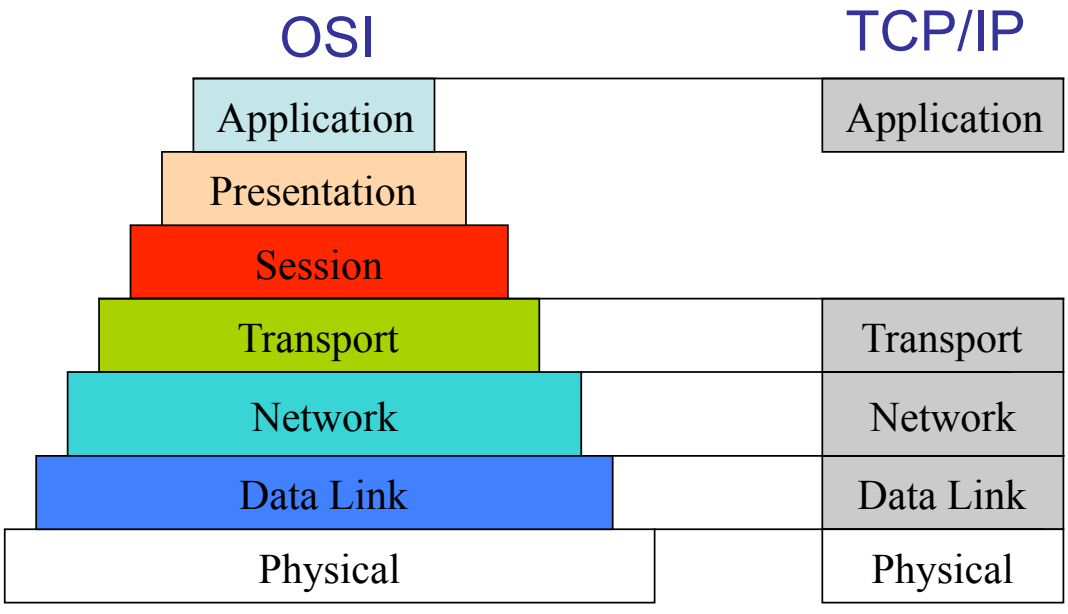
The Layers at Work



How does data flow?

- Data packets start at the Application Layer & moves down through the layers.
- When it reaches the Physical Layer it is ready to be sent over the medium, either in digital or analog form, using electrical signals, light, radio waves, or sound.
- The data is transmitted to the destination device.
- At the receiver, it travels up through the layers of the OSI model, reaching the user.
- As data moves down through the layers it is encapsulated - additional information is added as headers or trailers
- The data in the packet does not change

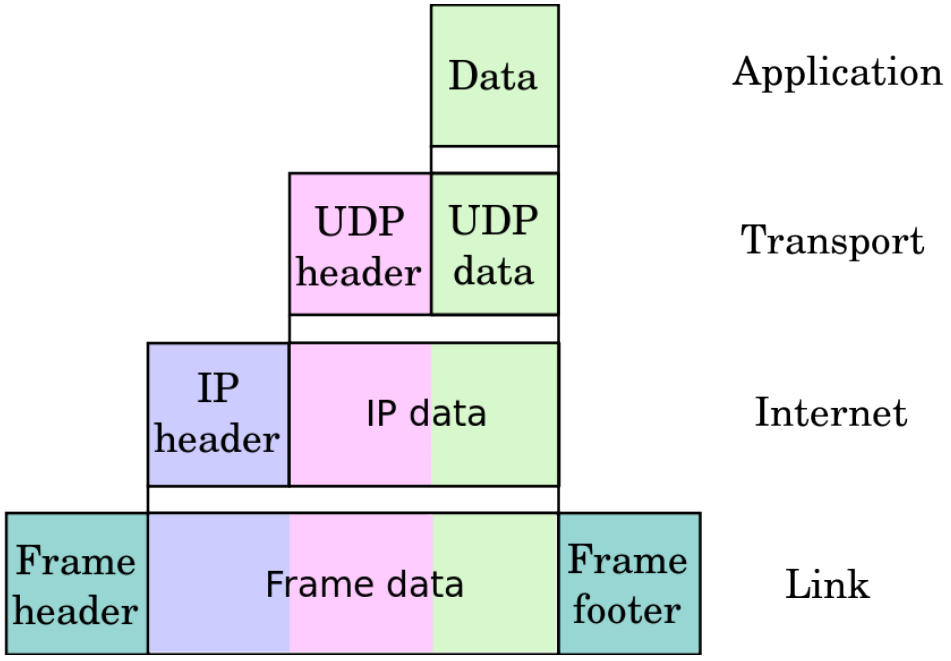
Modern networks use TCP/IP



The TCP/IP Model

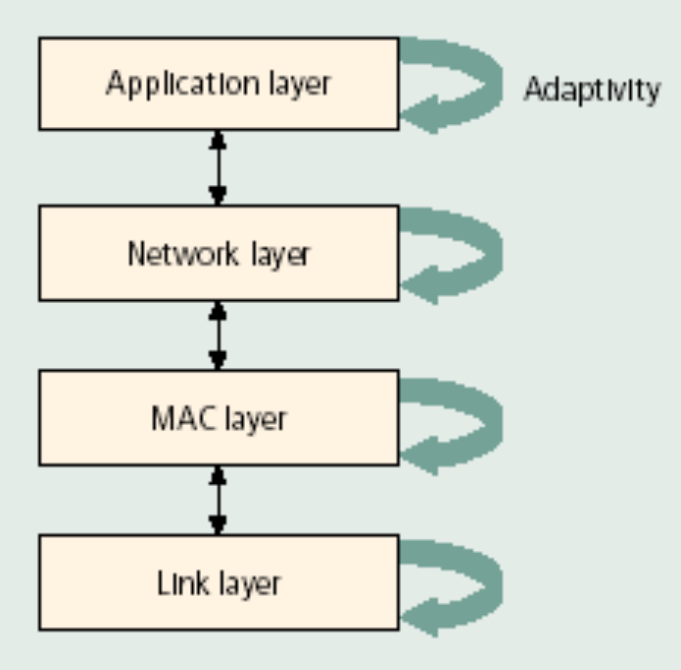
- Application Layer – concerned with how data at both ends is handled.
- Transport Layer – manages end-to-end flow of data and reliability.
- Network Layer – consists of several protocols, primary protocol is IP – which provides for routing and hierarchical addressing.
- Data Link Layer – manages transmission of data within nodes in the networks
- Physical Layer – used for managing the physical connection (not really part of TCP/IP)

Encapsulation in the TCP/IP model



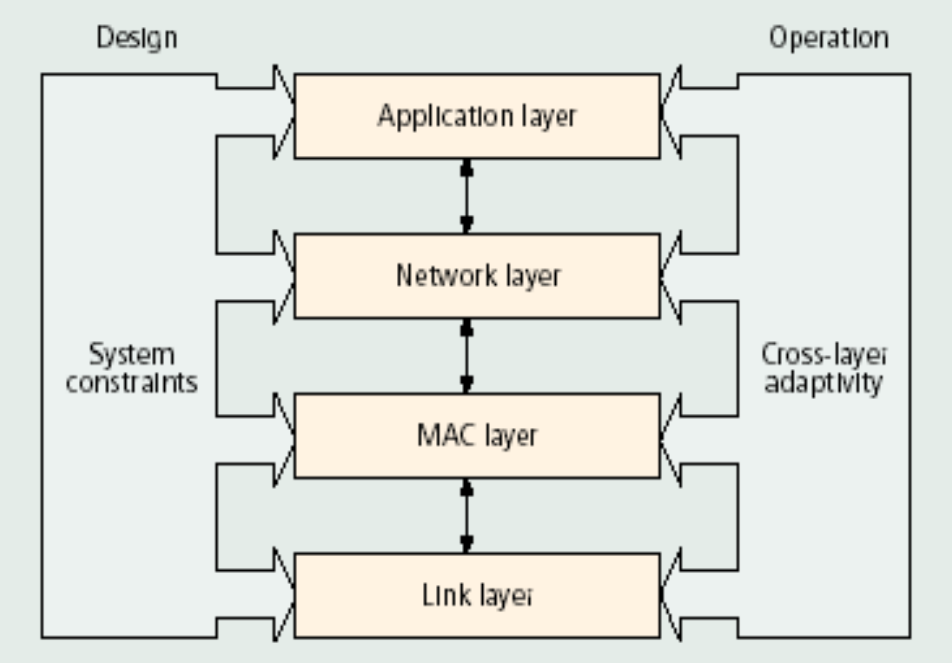
Benefits of Layered Approach

- Intercompatiblity
- Reuse
- Innovation
- Efficiency?



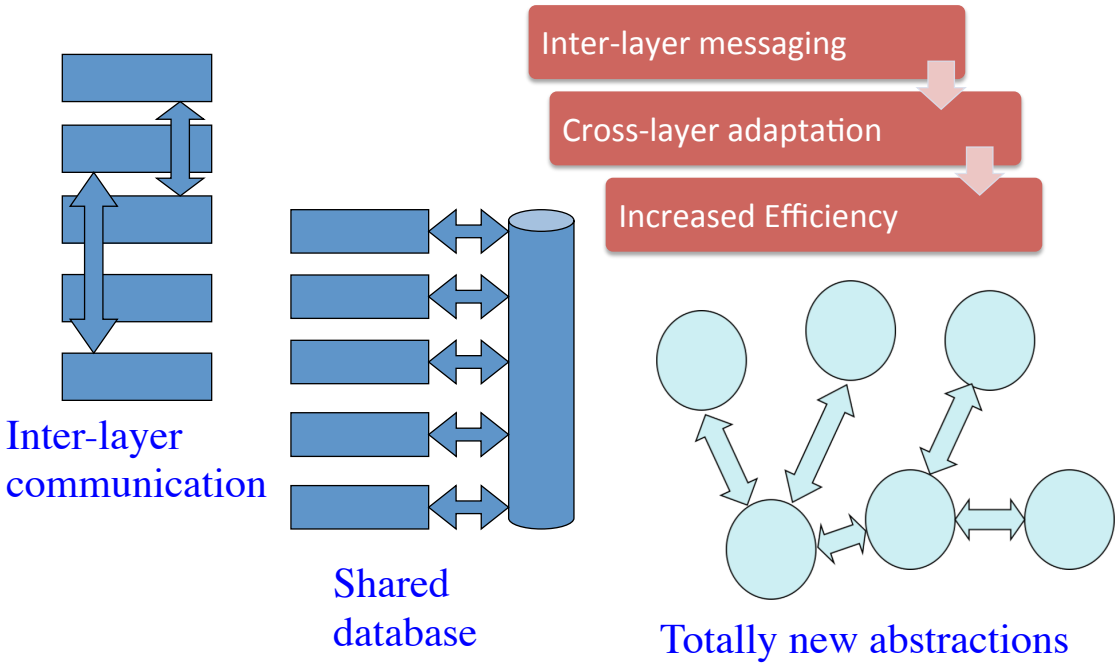
Source: Goldsmith&Wicker, 2002

Cross-layer Design



Source: Goldsmith&Wicker, 2002

Cross layer design



Additional Reading

- **Required Reading:**
  V. Srivastava and M. Motani, Cross-layer design: a survey and the road ahead, IEEE Communications Magazine, Volume 43, Issue 12, Dec. 2005 Page(s):112-119.
  http://wine.dnsalias.org/~motani/html/pubs/CrossLayerCommMag.pdf
- D. D. Clark, The Design Philosophy of the DARPA Internet Protocols, (Proc. SIGCOMM `88, Stanford, CA, August 1988, Vol. 18, No. 4)
  http://www.acm.org/sigs/sigcomm/ccr/archive/1995/jan95/ccr-9501-clark.pdf
- Hubert Zimmermann, OSI Reference Model - The ISO Model of Architecture for Open Systems Interconnection, IEEE Transactions on Communications, vol. 28, no. 4, April 1980, pp. 425 - 432.
  http://www.comsoc.org/livepubs/50_journals/pdf/RightsManagement_eid=136833.pdf
- L. Kleinrock. Research Areas in Computer Communication. *ACM Computer Communication Review*, 25(1), 1995.
  http://www.acm.org/sigs/sigcomm/ccr/archive/1995/jan95/ccr-9501-kleinrock.pdf
- Kurose & Ross, Chapter 1 (general), Section 1.5 (Layers)
- Bertsekas & Gallager, Data Networks, Section 1.3 on Layering, pp 17-32

SUMMARY of OSI Model (from Cisco)

- There was no standard for networks in the early days and as a result it was difficult for networks to communicate with each other.
- The International Organisation for Standardisation (ISO) recognised this. and researched various network schemes, and in 1984 introduced the Open Systems Interconnection (OSI) reference model.
- The OSI reference model has standards which ensure vendors greater compatibility and interoperability between various types of network technologies.
- The OSI reference model organizes network functions into seven numbered layers.
- Each layer provides a service to the layer above it in the protocol specification and communicates with the same layer's software or hardware on other computers.
- Layers 1-4 are concerned with the flow of data from end to end through the network and Layers 5-7 are concerned with services to the applications.

From Cisco Systems

LAYER 7: APPLICATION

- The application layer is the OSI layer that is closest to the user.
- It provides network services to the user's applications.
- It differs from the other layers in that it does not provide services to any other OSI layer, but rather, only to applications outside the OSI model.
- Examples of such applications are spreadsheet programs, word processing programs, and bank terminal programs.
- The application layer establishes the availability of intended communication partners, synchronizes and establishes agreement on procedures for error recovery and control of data integrity.

From Cisco Systems

LAYER 6: PRESENTATION

- The presentation layer ensures that the information that the application layer of one system sends out is readable by the application layer of another system.
- If necessary, the presentation layer translates between multiple data formats by using a common format.
- Provides encryption and compression of data.
- Examples :- JPEG, MPEG, ASCII, EBCDIC, HTML.

From Cisco Systems

LAYER 5: SESSION

- The session layer defines how to start, control and end conversations (called sessions) between applications.
- This includes the control and management of multiple bi-directional messages using dialogue control.
- It also synchronizes dialogue between two hosts' presentation layers and manages their data exchange.
- The session layer offers provisions for efficient data transfer.
- Examples : SQL, ASP(AppleTalk Session Protocol).
- Examples: SSL

From Cisco Systems

LAYER 4: TRANSPORT

- The transport layer regulates information flow to ensure end-to-end connectivity between host applications reliably and accurately.
- The transport layer segments data from the sending host's system and reassembles the data into a data stream on the receiving host's system.
- The boundary between the transport layer and the session layer can be thought of as the boundary between application protocols and data-flow protocols. Whereas the application, presentation, and session layers are concerned with application issues, the lower four layers are concerned with data transport issues.
- Layer 4 protocols include TCP (Transmission Control Protocol) and UDP (User Datagram Protocol).

From Cisco Systems

LAYER 3: NETWORK

- Defines end-to-end delivery of packets.
- Defines logical addressing so that any endpoint can be identified.
- Defines how routing works and how routes are learned so that the packets can be delivered.
- The network layer also defines how to fragment a packet into smaller packets to accommodate different media.
- Routers operate at Layer 3.
- Examples :- IP, IPX, AppleTalk.

From Cisco Systems

LAYER 2: DATA LINK

- The data link layer provides access to the networking media and physical transmission across the media and this enables the data to locate its intended destination on a network.
- The data link layer provides reliable transit of data across a physical link by using the Media Access Control (MAC) addresses.
- The data link layer uses the MAC address to define a hardware or data link address in order for multiple stations to share the same medium and still uniquely identify each other.
- Concerned with network topology, network access, error notification, ordered delivery of frames, and flow control.
- Examples :- Ethernet, Frame Relay, FDDI.

From Cisco Systems

LAYER 1: PHYSICAL

- The physical layer deals with the physical characteristics of the transmission medium.
- It defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining, and deactivating the physical link between end systems.
- Such characteristics as voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, physical connectors, and other similar attributes are defined by physical layer specifications.
- Examples :- EIA/TIA-232, RJ45, NRZ, 802.11

From Cisco Systems