Basics: Protocol Architectures

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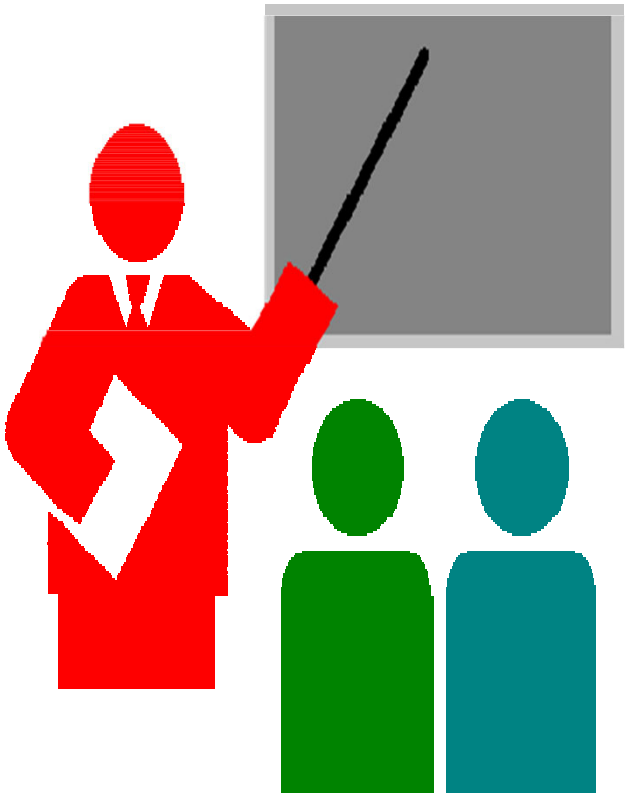
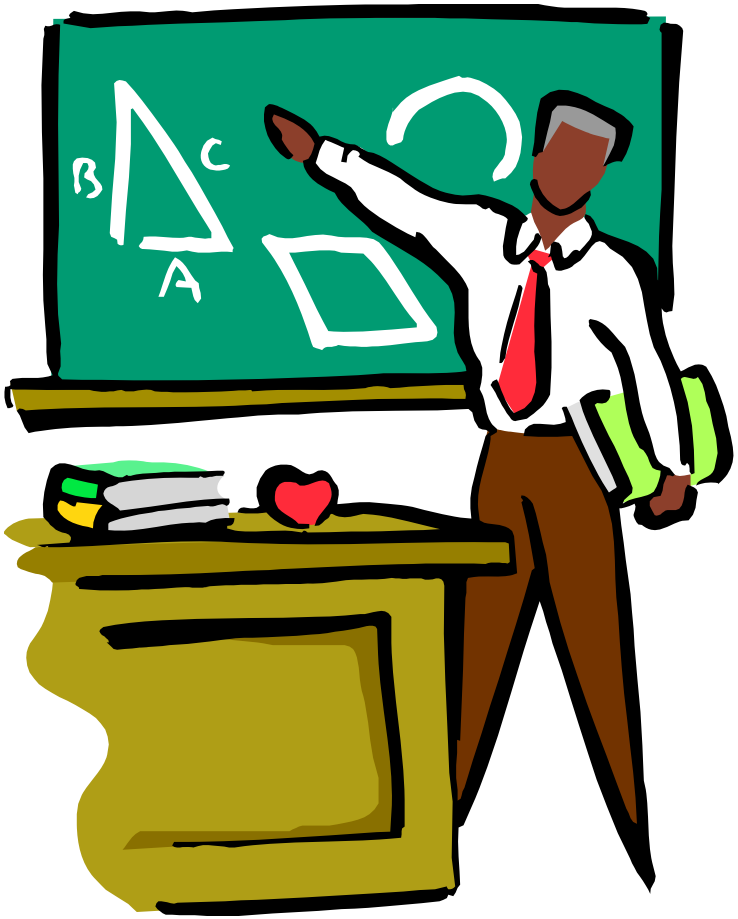
Protocol Architectures



- Layered Architectures
- Cross Layer Architectures

Layered Protocol Architectures

Layered protocol architectures



- 1 - Motivation , concepts and design issues
- 2 - Reference models

Motivation, concepts and design issues

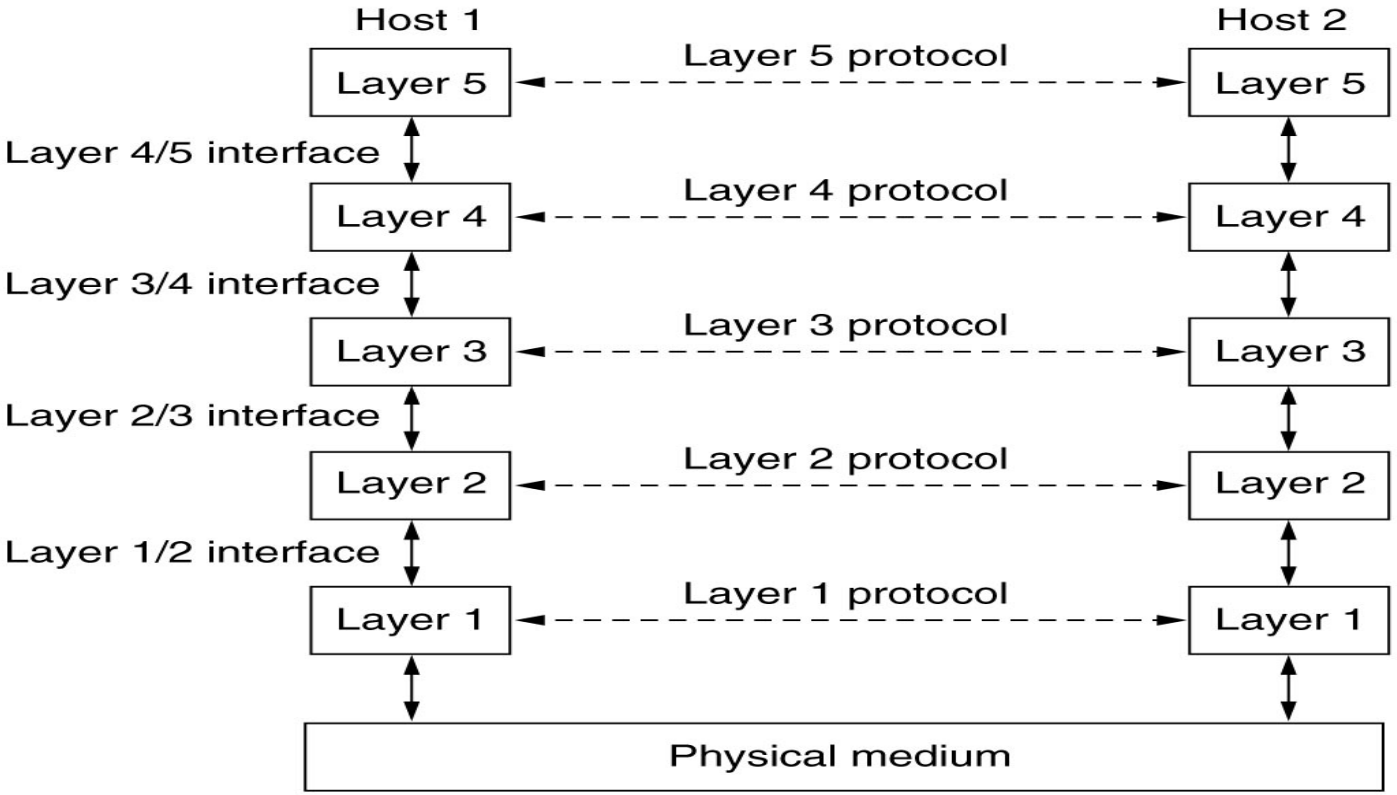


Figure 1.13 (Reference [1])

Motivation, concepts and design issues

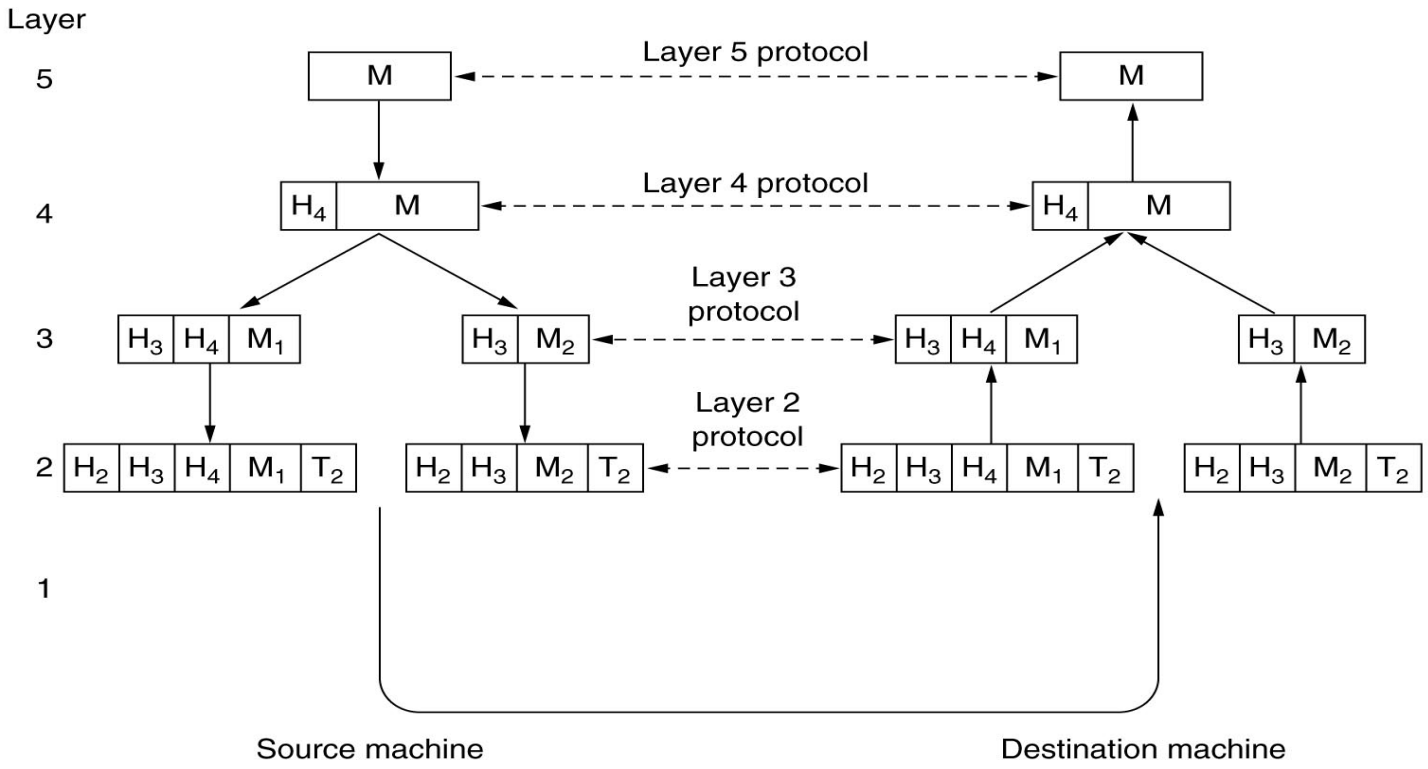


Figure 1.15 (Reference [1])

Motivation, concepts and design issues

- Why organize network software/firmware/hardware in a stack of layers?
  - A layer N provides a service to its user (Layer N+1) but keeps the details of its internal state and algorithms hidden
    - Hierarchisation
    - Modularization
    - Information hiding
    - Data encapsulation
    - Abstract data types
    - Object oriented programming

Motivation, concepts and design issues

- The key concepts
  - Protocol, protocol stack
  - Interfaces and services
  - Network architecture

Motivation, concepts and design issues

- Protocol
  - Rules governing the exchange of messages between peer layers (or entities in general)
    - Syntax
    - Semantics
    - Sequencing
- Protocol stack
  - List of protocol used by a given system, one per layer

Motivation, concepts and design issues

- Interface and services
  - Between adjacent layers
    - Primitive operations and services made available by the lower layer to the upper layer
  - Service specification
    - Set of primitives operations available to a user process to access the service
      - Connection – oriented services
      - Connection-less services

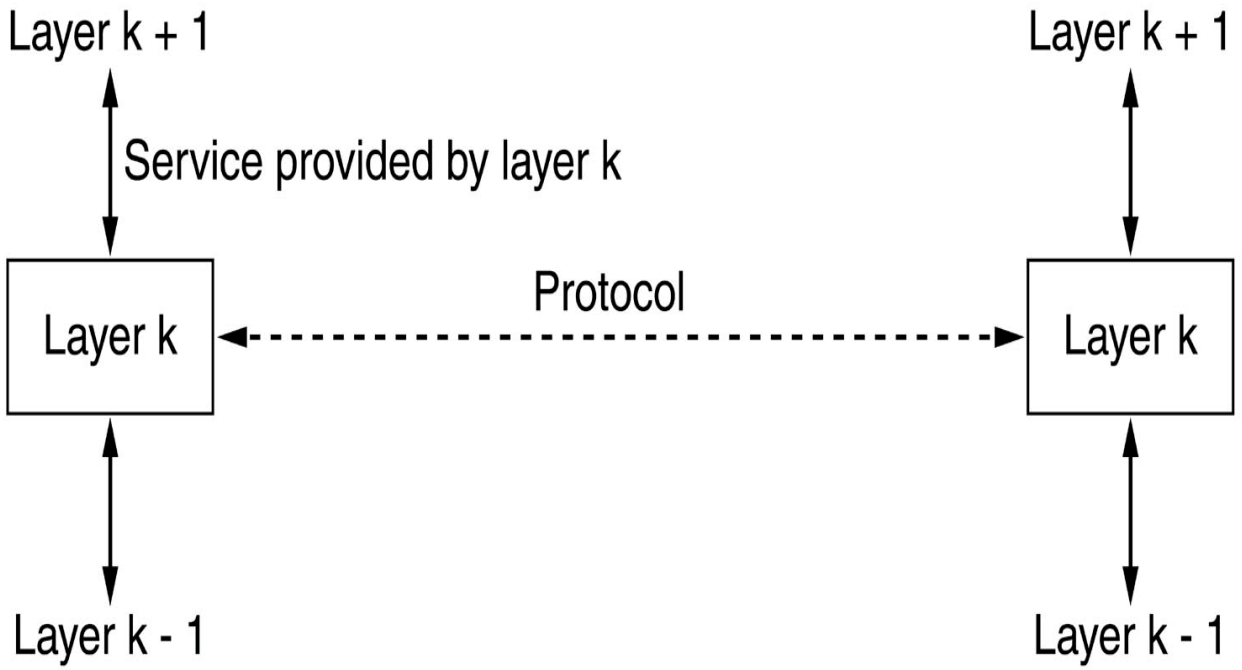
Motivation, concepts and design issues

- Interfaces and services
  - Example of 5 service primitives for implementing a simple – connection oriented service (figure 1.17 – reference [1])

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Motivation, concepts and design issues

- Relationship between services and protocols
  - Figure 1.19 – reference [1]



Motivation, concepts and design issues

- Design issues for the layers
  - Addressing
  - Error control
  - Flow control
  - Routing

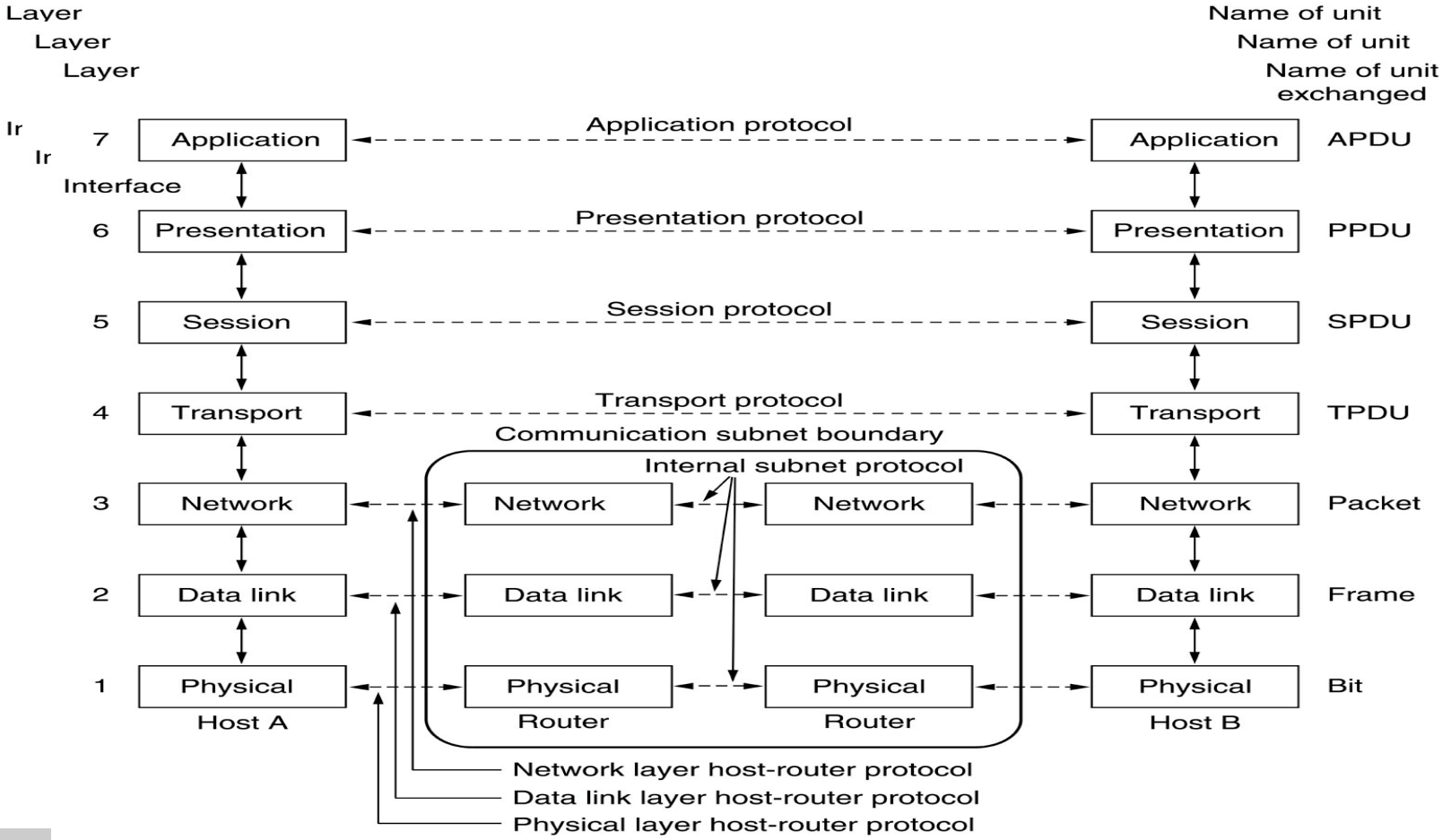
Motivation, concepts and design issues

- Network architecture
  - Set of layers and protocols
  - Examples
    - OSI reference model
    - TCP/IP reference model

Reference model

OSI reference model

– Figure 1.20 – reference [1]



Reference model

- OSI Reference model
  - The 7 layers
    - Application
    - Presentation
    - Session
    - Transport
    - Network
    - Data link
    - Physical

Reference model

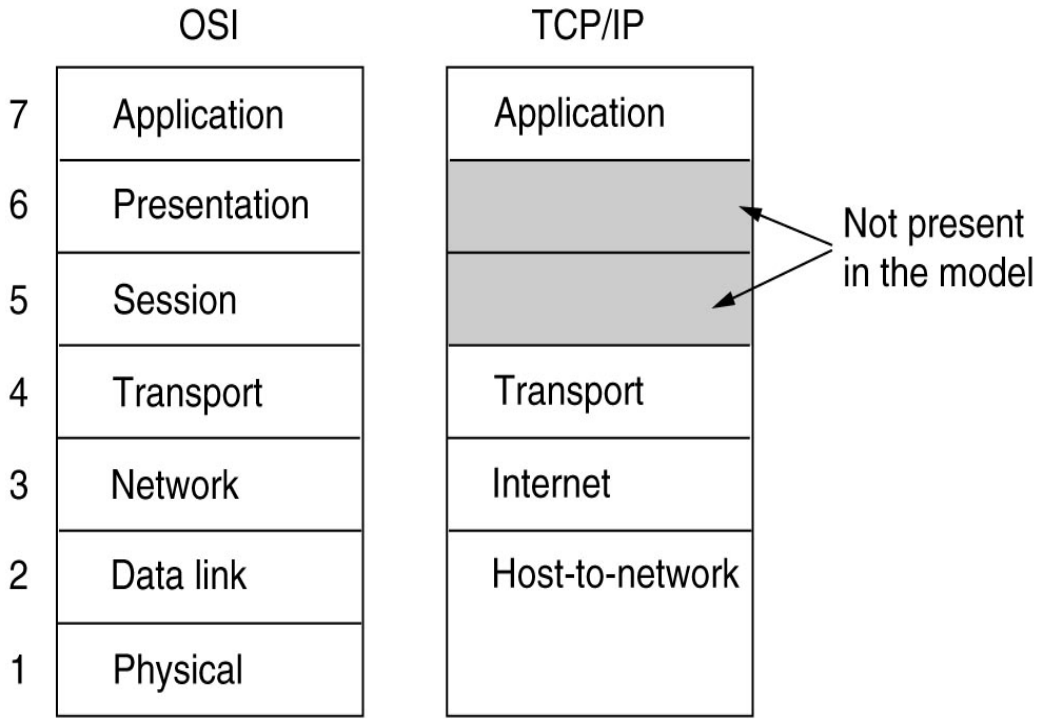
- OSI Reference model
  - Application Data Unit (APDU)
  - Session Data Unit (SPDU)
  - Transport Data Unit (TDU)
  - Packet
  - Frame
  - Bit

Reference model

- OSI Reference model
  - Key issues
    - Bad timing
    - Bad technology
    - Complexity leading to bad implementations

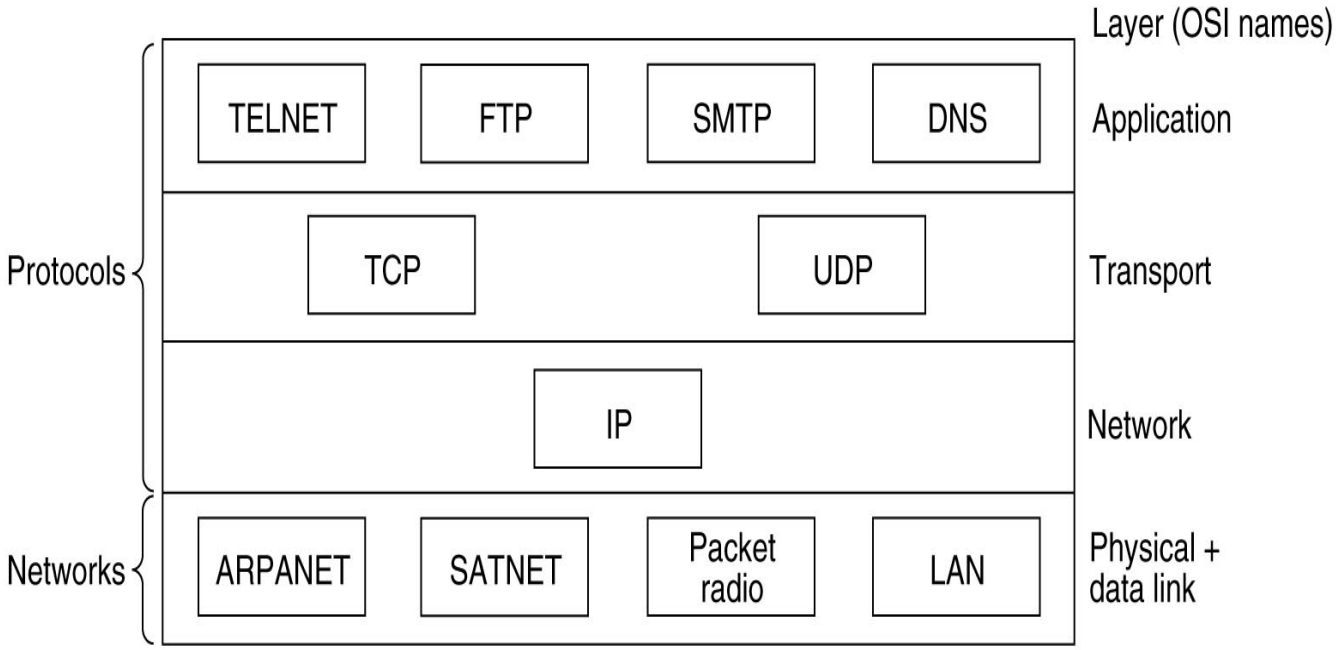
Reference model

- TCP / IP reference model
  - Figure 1.21 (Reference [1])



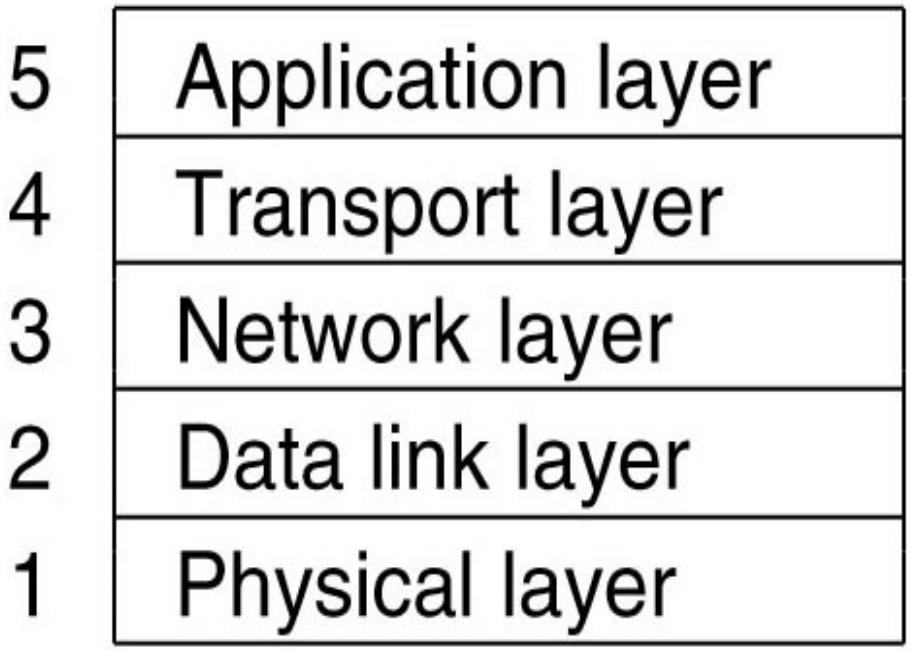
Reference model

- TCP / IP reference model
  - Figure 1.22 (Reference [1]) – Protocols and networks in the TCP/IP model initially



Reference model

- Hybrid model
  - Figure 1.24 (Reference [1])



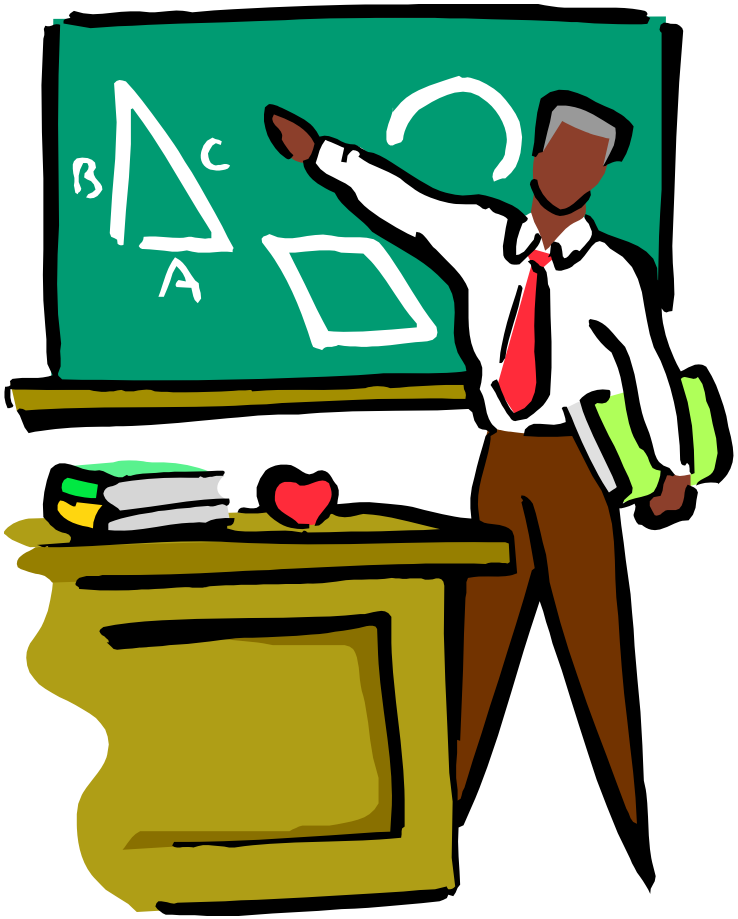
References

1. A. Tanenbaum, Computer Networks, , 6th Edition, 2021

2. Kurose and Rose, Computer Networking: A Top Down Approach, 7th Edition, Pearson, 8th edition planned for 2021

Cross Layer Protocol Architectures

Cross Layer Protocol Architectures



- 1 - Definition and motivation
- 2 - Architectural approaches
- 3 - Implementation approaches
- 4 - A word of caution

Definition and motivation

- Essentials of layered protocol architectures (Reminder)
  - Communication allowed only between adjacent layers and only via procedures calls and responses
  - Services at different layers realized by designing protocols at these layers

Definition and motivation

- Definition of cross layer design
  - Violation of the principles of layered protocol architectures
    - Examples
      - Allowing communications between non adjacent layers
      - Sharing variables between layers
      - Designing protocols that span several layers

Definition and motivation

Main motivation for cross layer design

- Performance improvements, especially in wireless environments
  - An example
    - TCP sender assumes packet errors are indicators of networks congestion and slow down sending rates
      - » Case of wired links: true
        - » Need to slow down

Definition and motivation

Main motivation for cross layer design

- Performance improvements, especially in wireless environments
  - An example
    - TCP sender assumes packet errors are indicators of networks congestion and slow down sending rates
      - » Case of wireless links
        - » Not always true
        - » May be indicators of errors on physical and data link layers
        - » Information from physical and data link layers to transport layer (i.e. TCP) needed to make correct decision (i.e. slow down or speed up)

Definition and motivation

Main motivation for cross layer design

- What makes wireless environments different
  - Channels vary over time and space leading to bursts of errors
    - Motion of wireless device
    - Surroundings
      - » Small and large scale variations
        - » Channels states can switch from good to bad within milliseconds
        - » Some users may demand more channel access than others due to their location or velocity

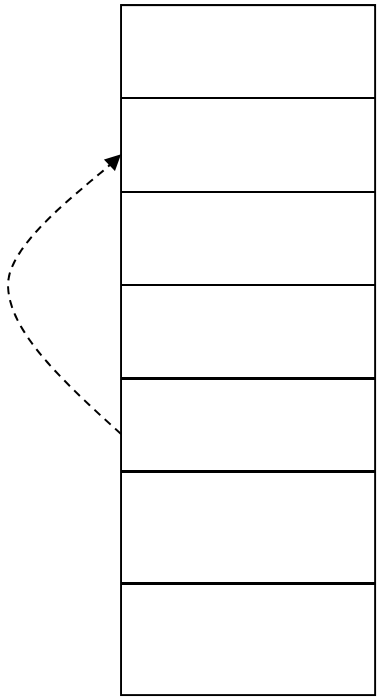
Architectural approaches

1. Design of new interfaces
2. Merging of adjacent layers
3. Design coupling without new interfaces
4. Vertical calibration

Architectural approaches

1. Creation of new interfaces

- Upward information flow

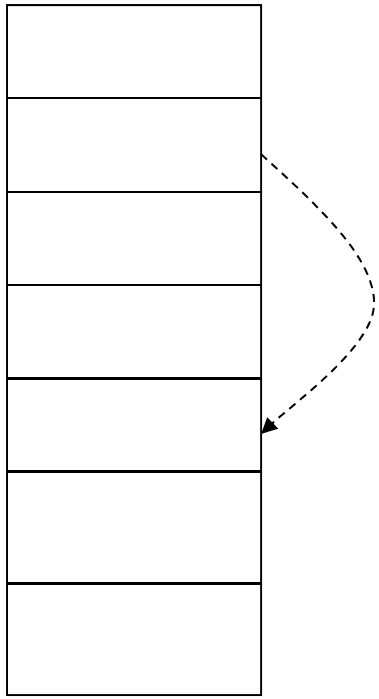


Ex: Explicit notifications from lower layers to TCP (e.g. explicit congestion/high error rate notification)

Architectural approaches

1. Creation of new interfaces

- backward information flow

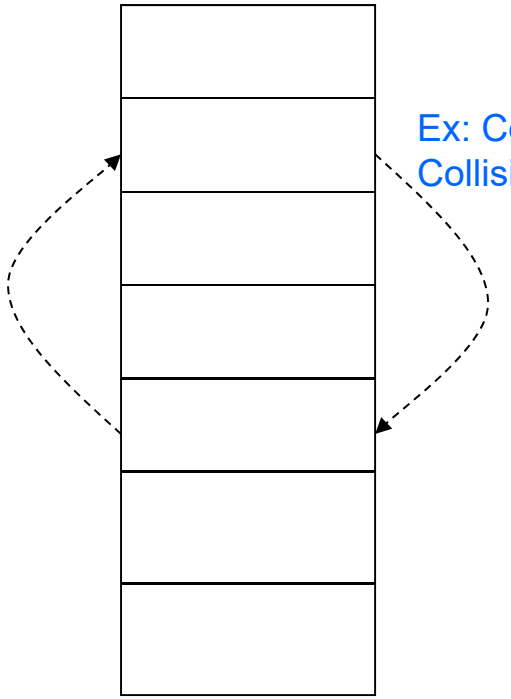


Ex: Applications can inform link layers about delay requirements to enable prioritization at that layer

Architectural approaches

1. Creation of new interfaces

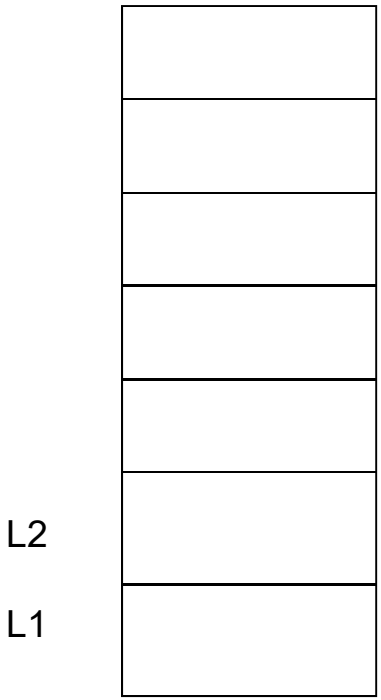
- Upward and backward information flow

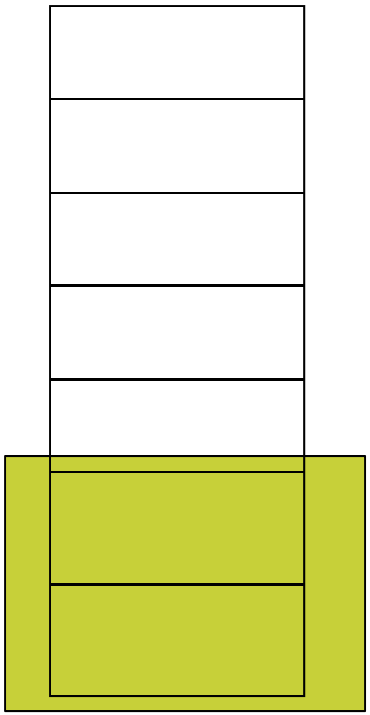


Ex: Collaboration between physical and link layer for Collision resolution

Architectural approaches

2. Merging of adjacent layers

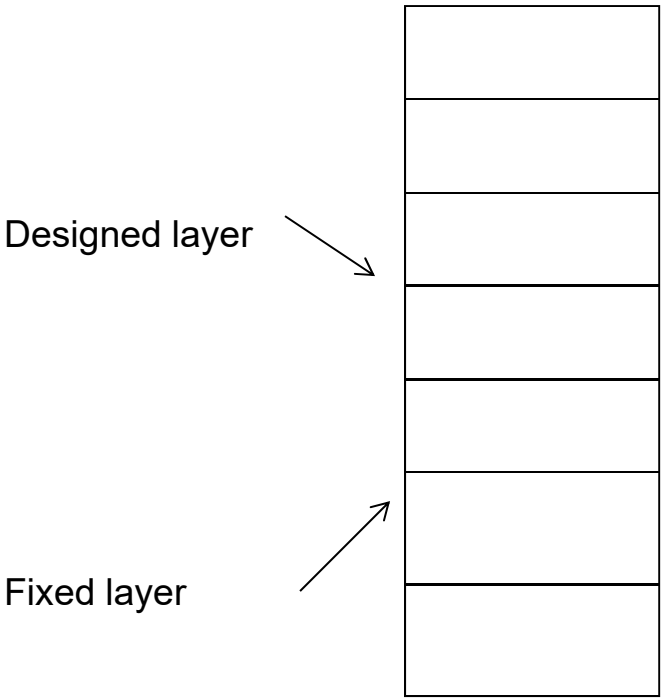




Rather uncommon

Architectural approaches

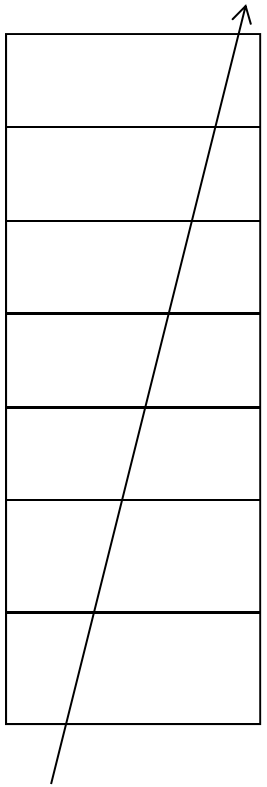
3. Design coupling without new interfaces



Ex: new capabilities of physical layer (e.g. possibility of receiving several packets at the same time) may trigger the redesign of a new link layer

Architectural approaches

3. Vertical calibration



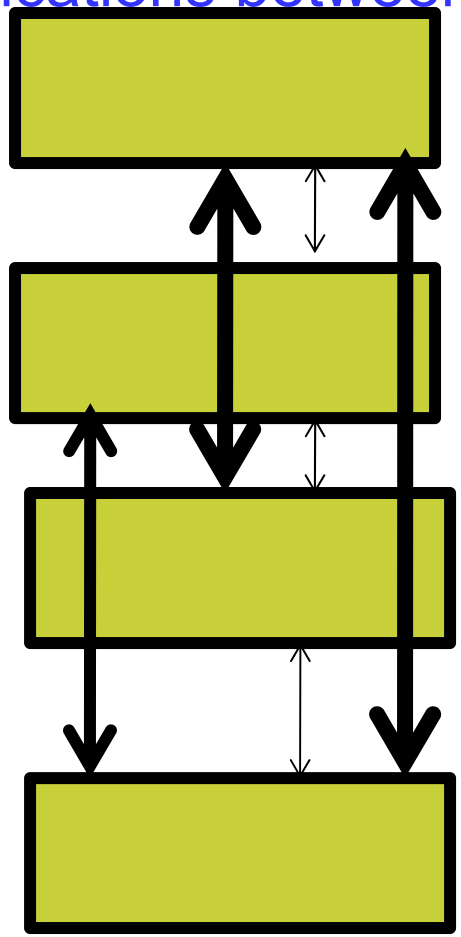
Ex: Joint tuning of parameters across the layers to achieve a specific goal

Implementation approaches

1. Direct communications between the layers
2. Shared data bases
3. New abstractions (e.g. heap)

Implementation approaches

1. Direct communications between layers

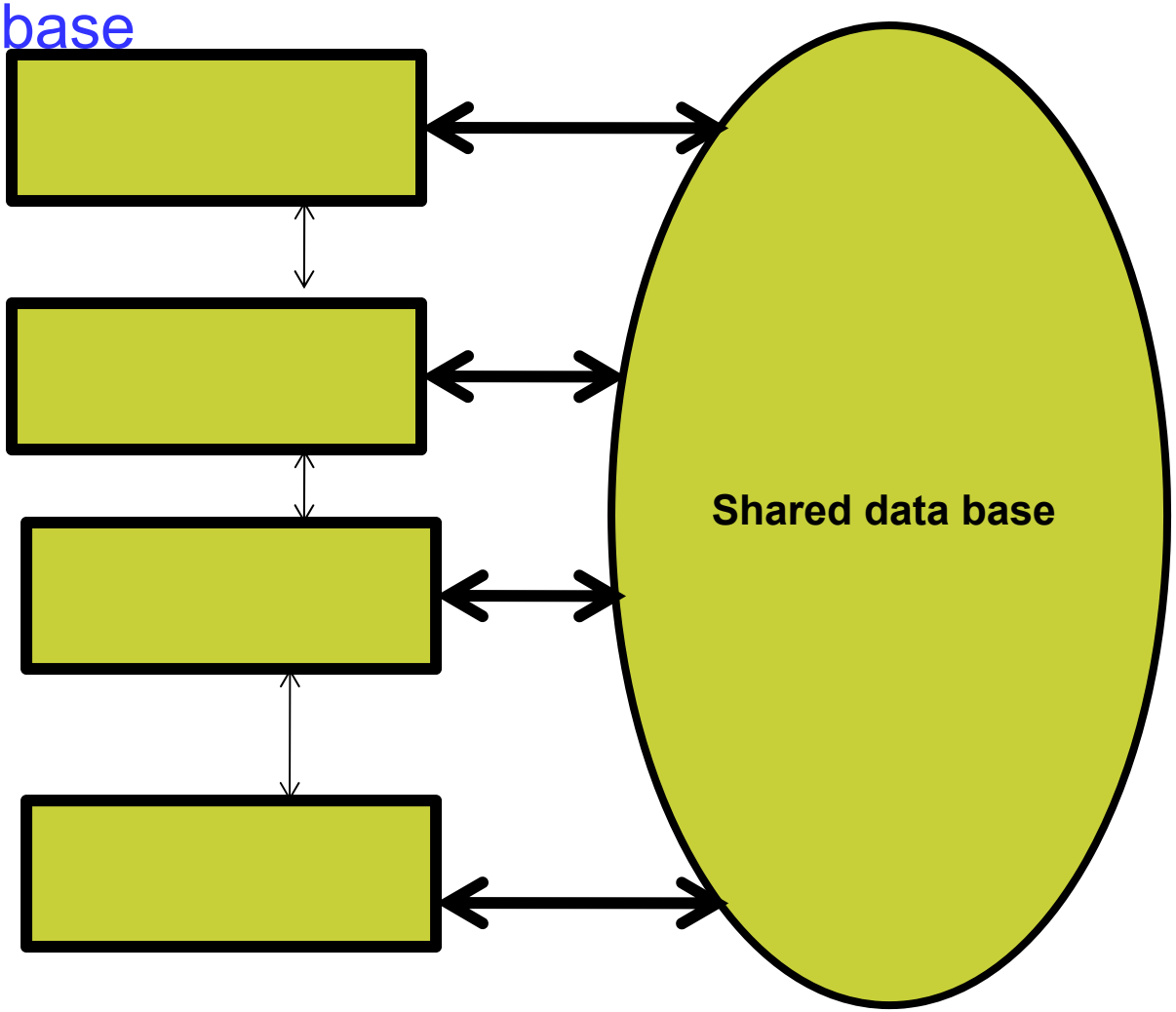


Implementation approaches

1. Direct communication between layers
   - Examples of realizations
     - Protocol headers
     - Internal packets
   - Usage / suitability
     - When few cross layers interactions are needed

Implementation approaches

2 . A shared data base



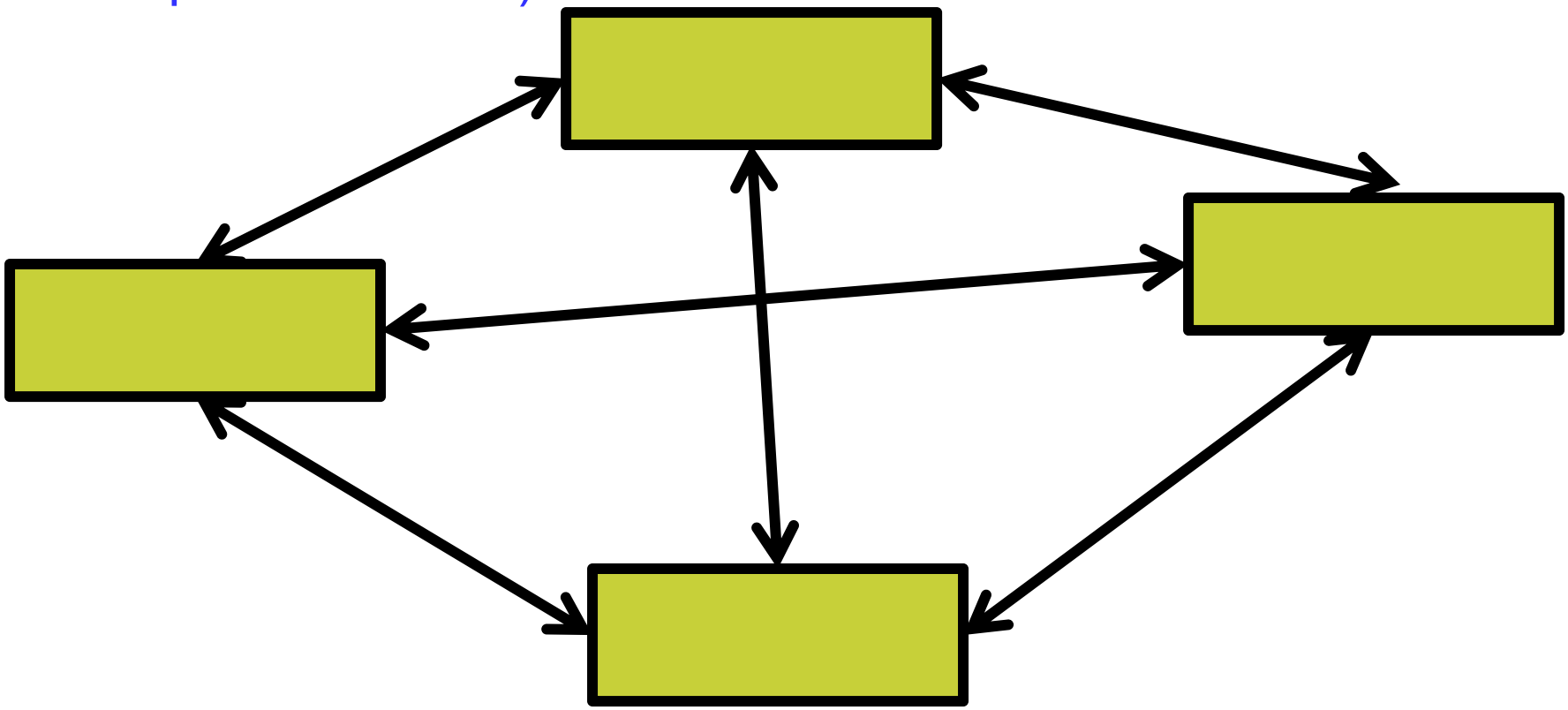
Implementation approaches

2. Shared data base

- Realization
  - Quite challenging
    - Interface between layers and the data base
    - Data base structure
- Usage / suitability
  - Most cases, especially vertical calibration

Implementation approaches

3. New abstractions (e.g. protocol heap instead of protocol stack)



Implementation approaches

2. New abstractions

- Realization
  - Even more challenging
    - Change the way we think about protocol implementation
- Usage / suitability
  - A lot of potential
    - Greater flexibility

A word of caution

- Benefits may not offset potential detrimental effects
  - Some illustrations
    - 1. Unintended consequences
      - » Tuning a parameter in layer K, to meet a specific need of layer X, may have the opposite effect on a parameter at layer B.
    - 2. “Chaos”
      - » Spaghetti – like code difficult to maintain
    - Bad interactions between cross layers design

The End