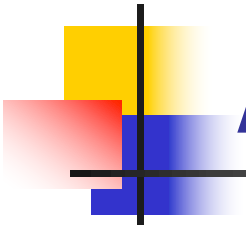
Functionalities and Decomposition

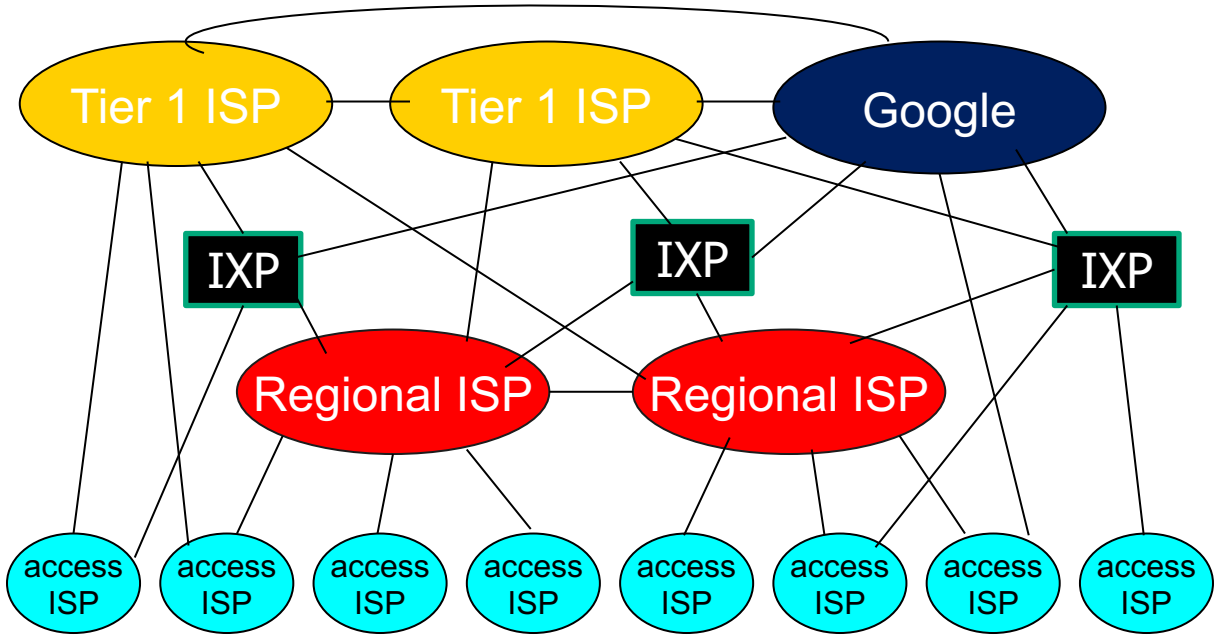
CSC/ECE 570 Computer Networks



Agenda

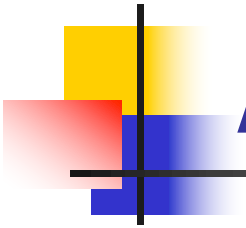
1. Internet Structure
2. Functionalities and Decomposition

Internet structure: network of networks



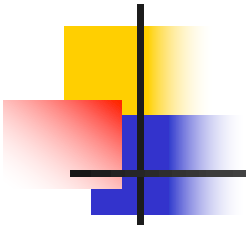
at center: small # of well-connected large networks

- "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
- content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs



Agenda

1. Functionalities and Decomposition



Managing Scale

- Modularizing functionality
  - Separate concerns, flexibly re-use
  - Layers
- Specializing equipment
  - Optimize for performance
  - Discard unnecessary function
- Coordinating distributed facility
  - Configuration
  - Auto-configuration
  - Protocols

    - used to exchange information between peer layers

Equipment (how frames are being delivered)

Hub

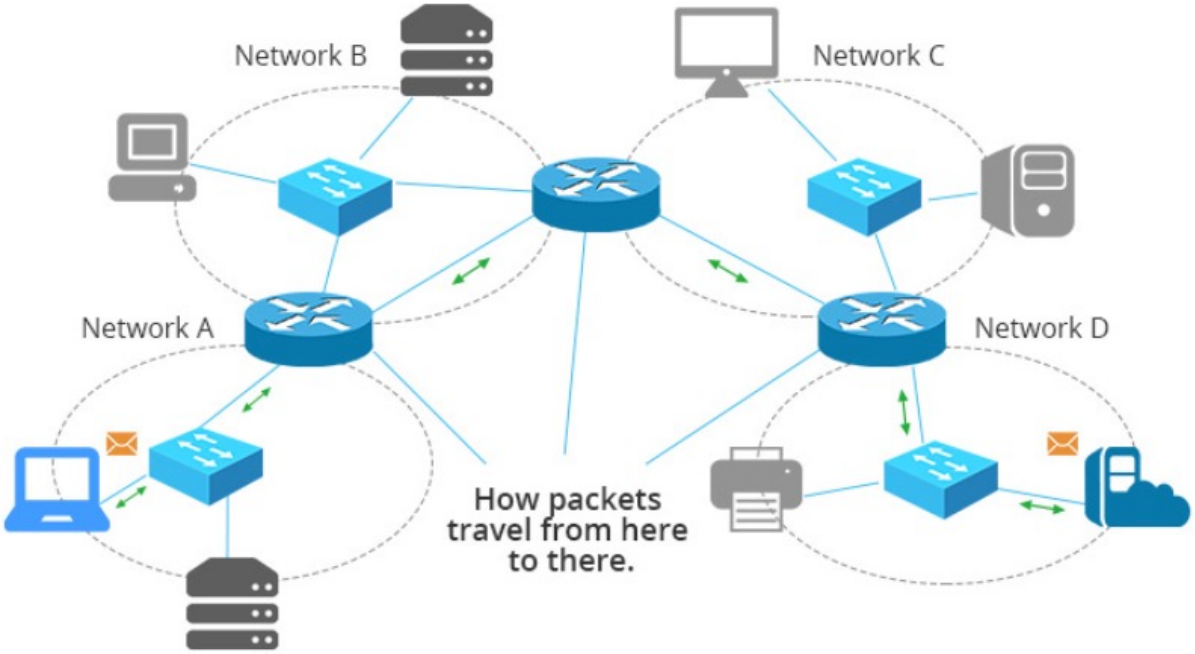
broadcast to every one of its ports

Switch

knows exactly which port to send it to

Equipment (how packets are being delivered)

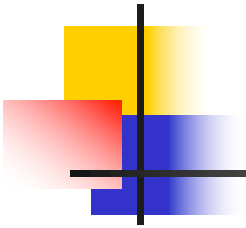
Router



Connects multiple networks together and directs traffic between them

Equipment

template	Hub	Switch	Router
Layer	Physical layer	Data link layer	Network layer
Function	To connect a network of personal computers together, they can be joined through a central hub	Allow connections to multiple devices, manage ports, manage VLAN security settings	Direct data in a network
Data Transmission form	electrical signal or bits	frame & packet	packet
Used in(LAN, MAN, WAN)	LAN	LAN	LAN, MAN, WAN



Managing Scale

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What's a protocol?

Human protocols:

- "what's the time?"
- "I have a question"

… specific msgs sent

… specific actions taken when msgs received, or other events

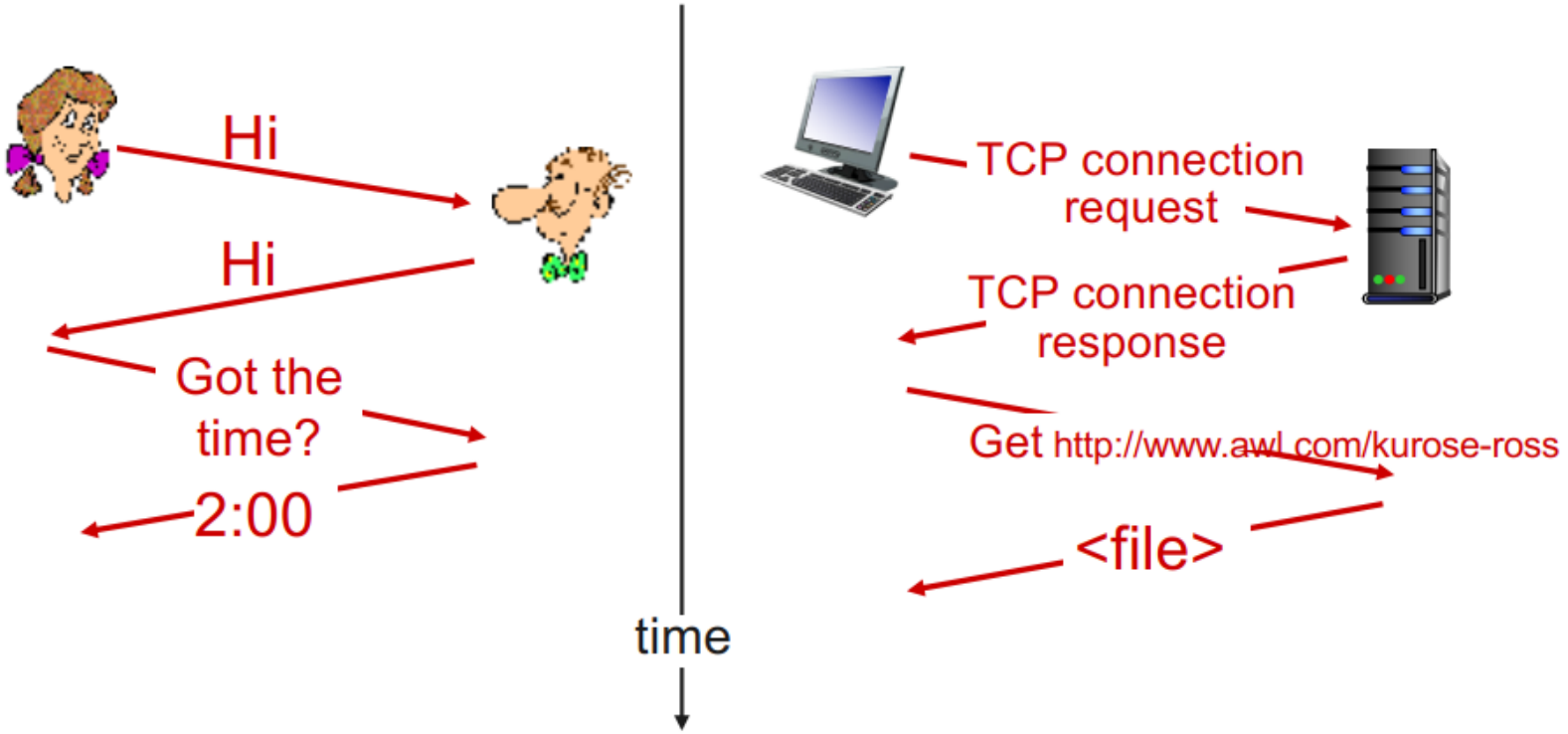
network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

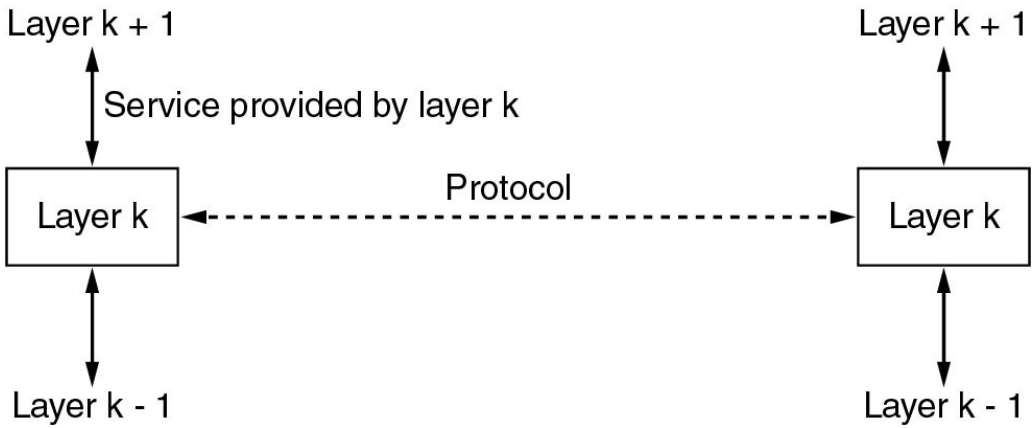
a human protocol and a computer network protocol:



Service view of protocol

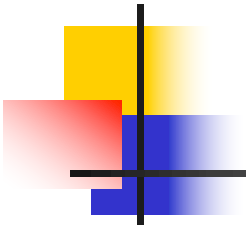
- A protocol is a software module providing a *service*
- ftp provides *reliable file transfer service*
- Peer entities use a protocol to provide a service to a higher-level peer entity

- Service interaction between modules constrained to very specific pattern → layering



Software Protocols

- *Syntax* of a message
  - What fields does it contain?
  - In what format?
- *Semantics* of a message
  - What does a message/field mean?
- *Actions* to take on receipt of a message
  - What to do when some event (message reception, timeout) occurs?

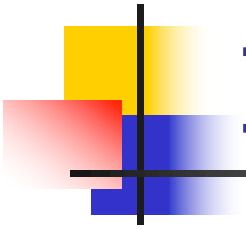


The importance of being layered

- Breaks up a complex problem into smaller manageable pieces
  - can compose simple service to provide complex ones
  - for example, WWW (HTTP) is Java layered over TCP over IP (and uses DNS, ARP, DHCP, RIP, OSPF, BGP, PPP, ICMP)
- Abstraction (hiding) of implementation details
  - separation of implementation and specification
  - can change implementation as long as service interface is maintained
- Can reuse functionality

Some terminology

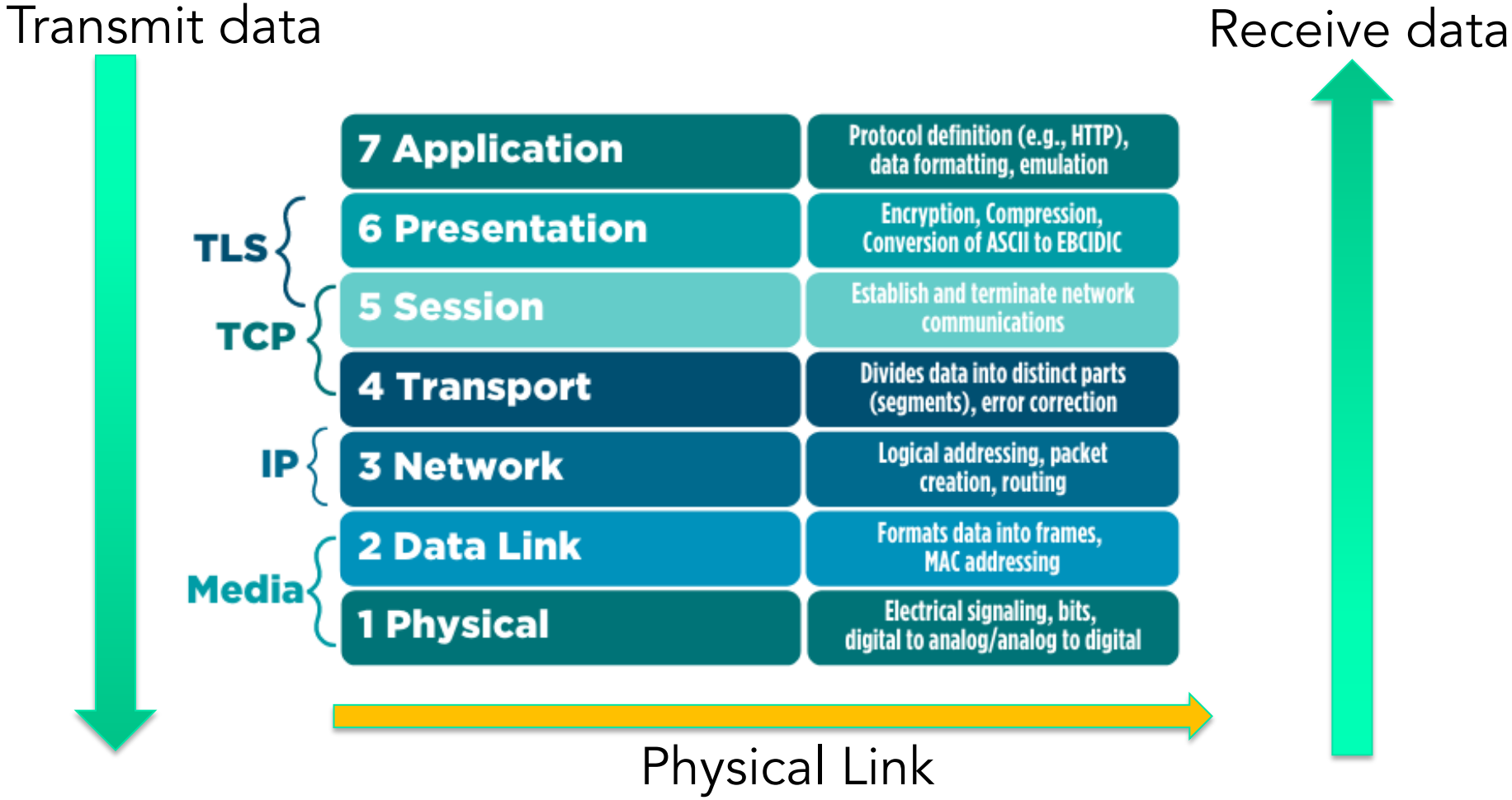
- *Service access point (SAP)*
  - Interface between layers
- *Protocol data units (PDUs)*
  - Structured bits exchanged by peer protocols at a layer
- *Service data units (SDUs)*
  - Unstructured bits received from (or delivered to) higher layer
- *Encapsulation*
  - Process of making PDU out of SDU
- PDU = SDU + optional header or trailer



ISO OSI reference model

- A set of protocols is *open* if
  - protocol details are publicly available
  - changes are managed by an organization whose membership and transactions are open to the public
- A system that implements open protocols is called an *open system*
- International Organization for Standards (ISO) prescribes a standard to connect open systems
  - *open system interconnect (OSI)*
- Has greatly influenced thinking on protocol stacks

OSI Protocol Stack

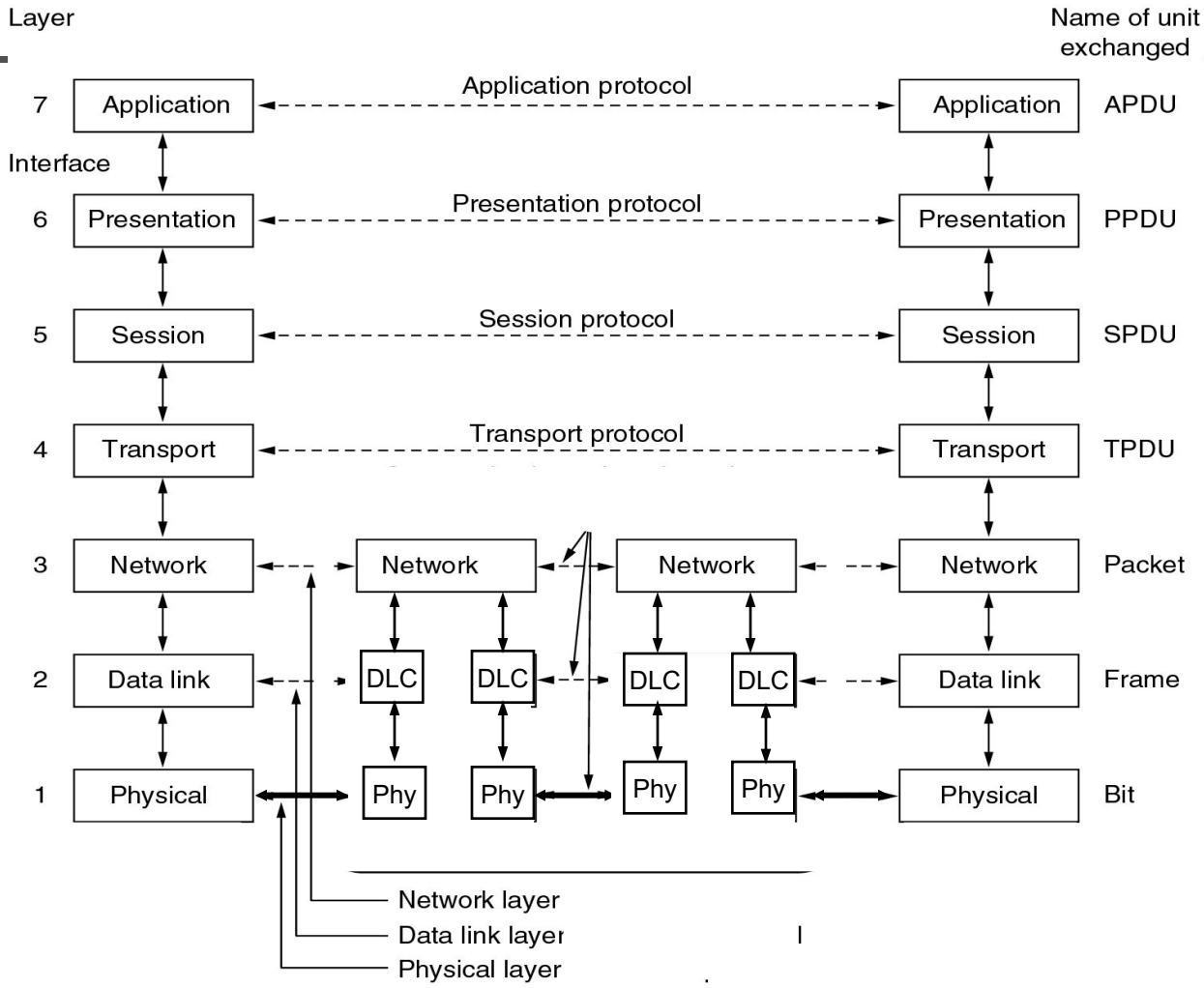


Organization of air travel

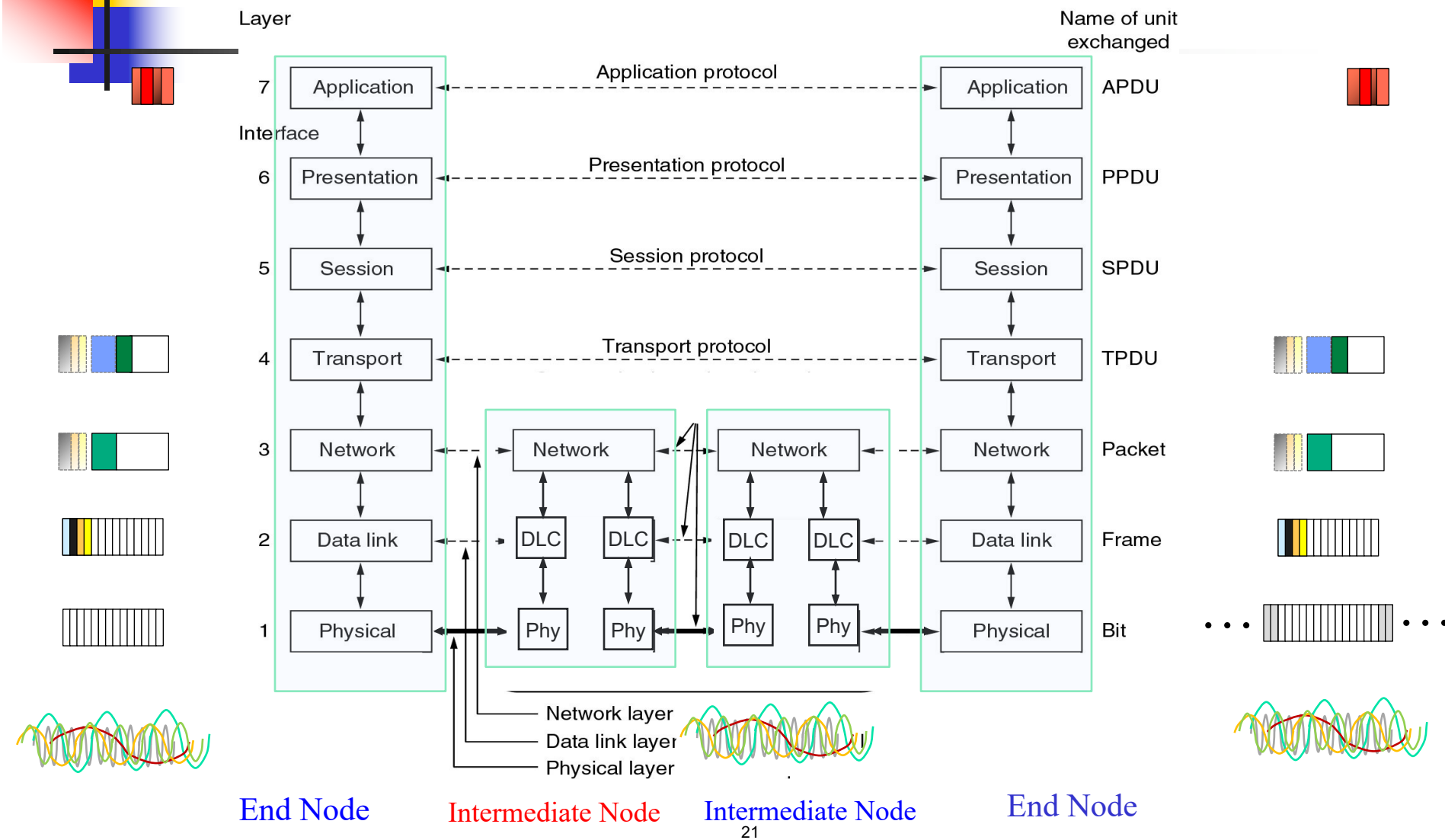
The seven layers in OSI model

End-to-end	Application	Top level user of the system
	Presentation	Resolve platform issues (data representation, possibly encryption)
	Session	Full-duplex, expedited data delivery, session synchronization
	Transport	Error control, flow control, multiplex Reliability
Node-to-node	Network	Concatenates links to form end-to-end abstraction
	Data Link Control	Organizes bit transmissions into frame transmissions (LLC, MAC sublayers)
	Physical	Moves bits between physically connected end-systems

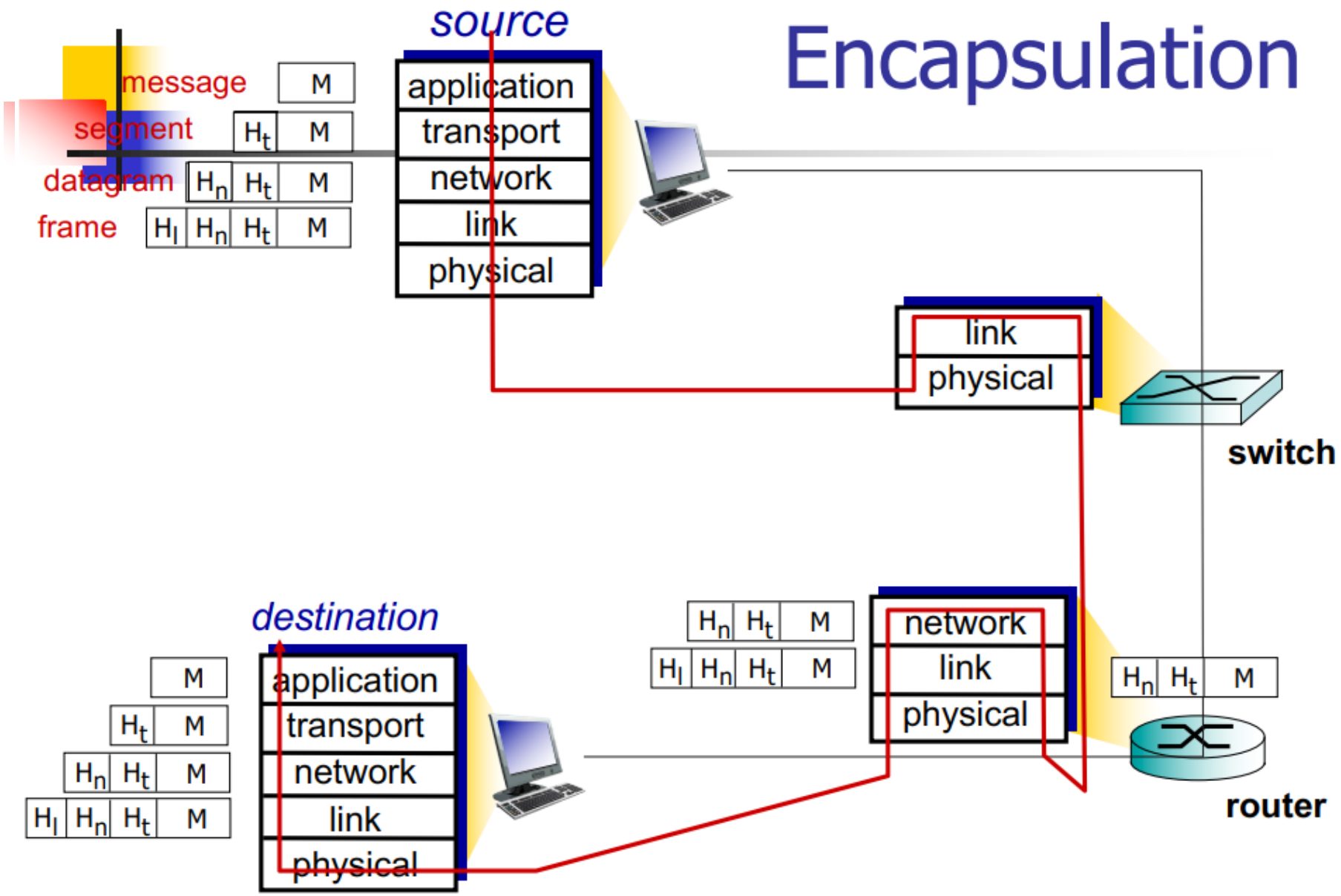
Peer Processes



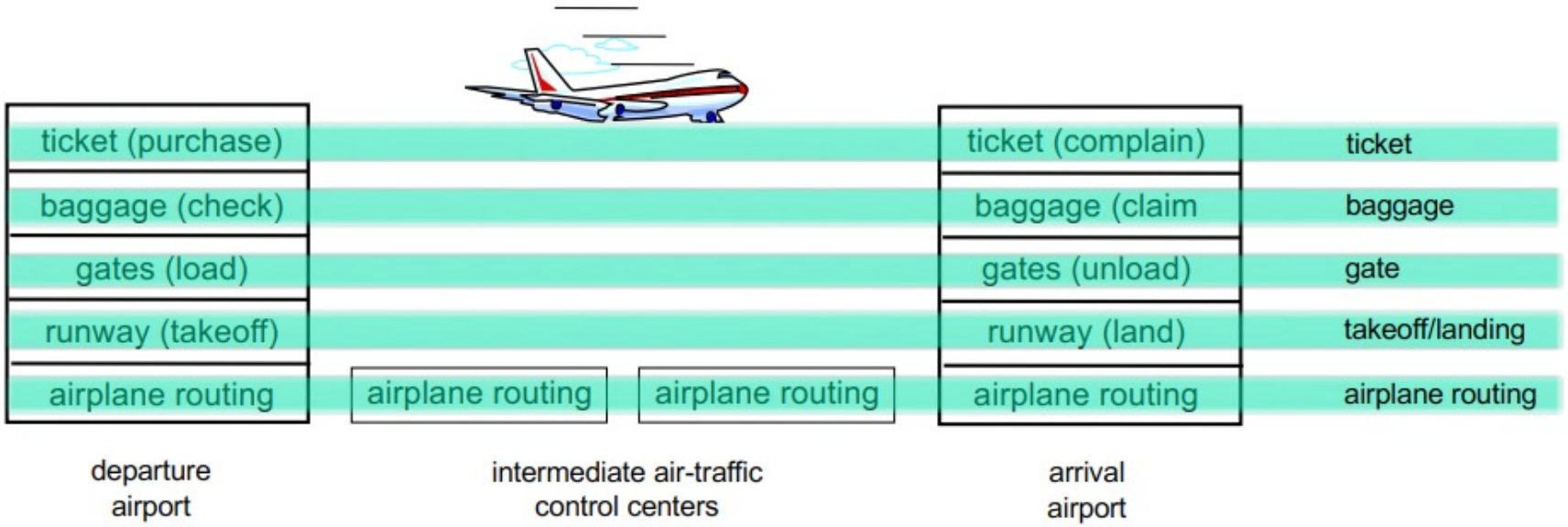
Peer Processes



Encapsulation



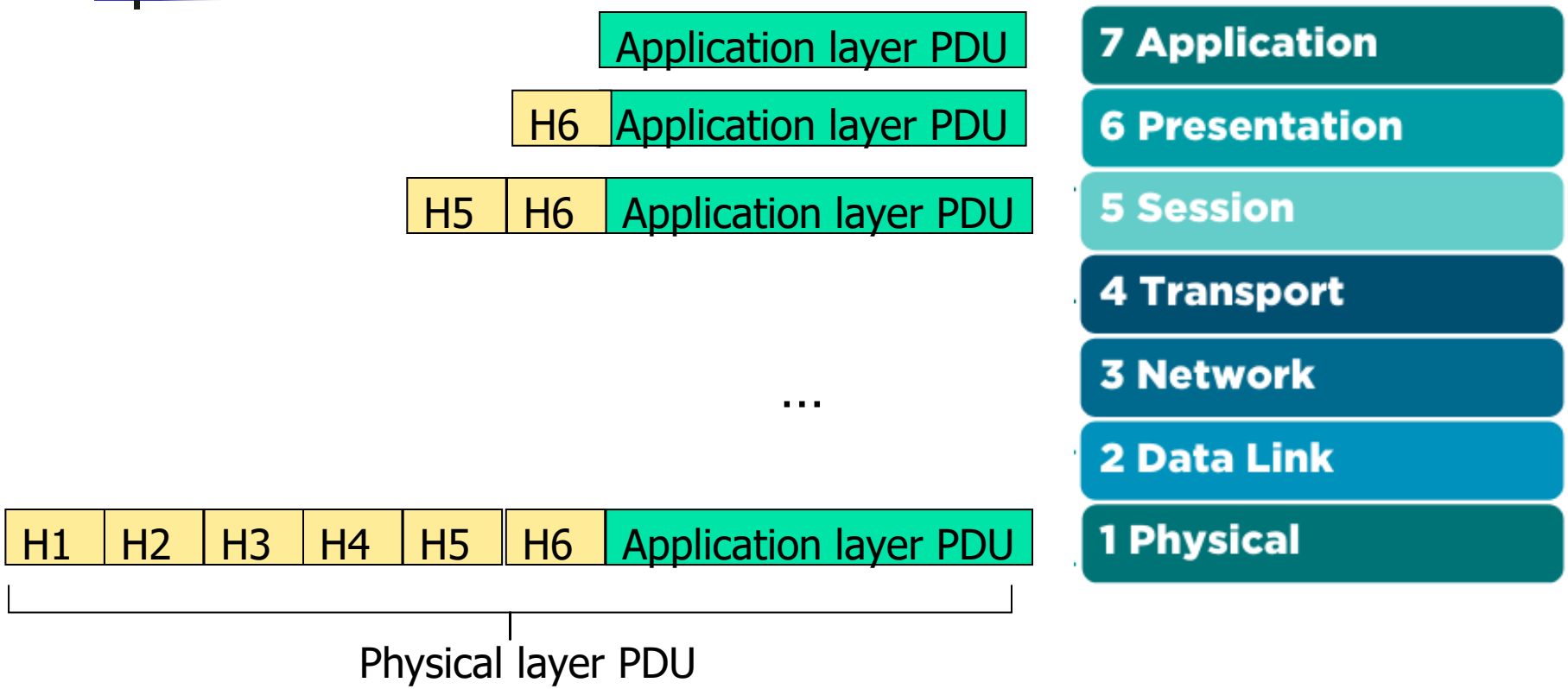
Layering of airline functionality



layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below/above

Protocol data units (PDUs)



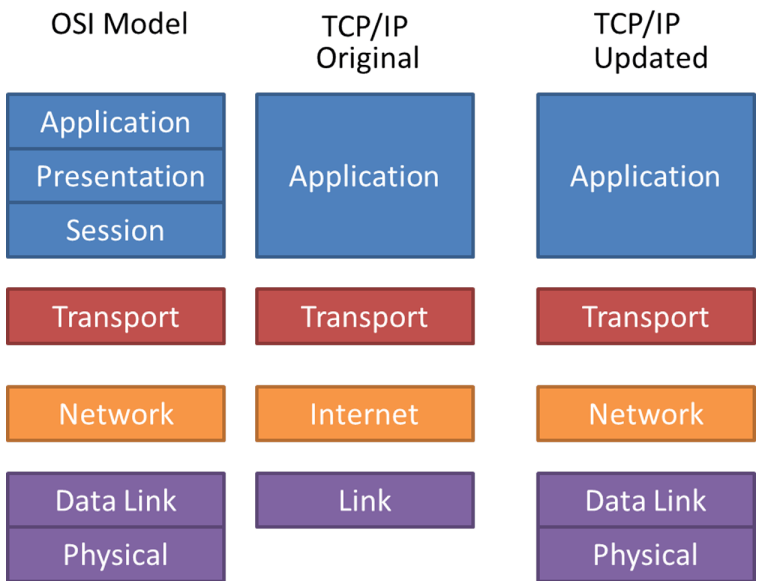
percentage bit overhead = (H1+H2+…+H6)/Application layer PDU

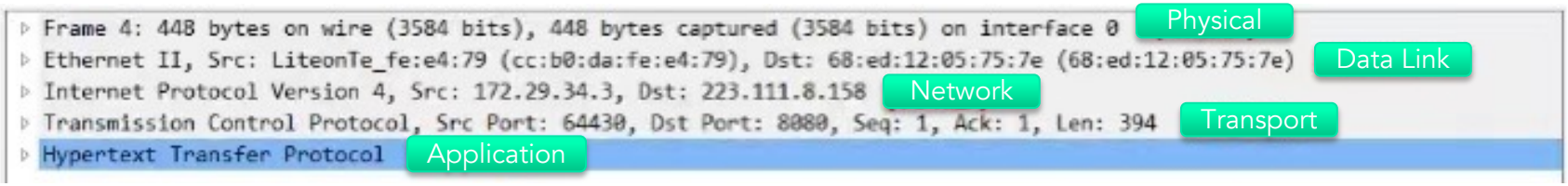
TCP/IP Protocol Suite

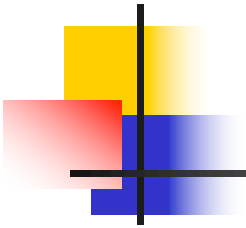
- Differences between OSI and TCP/IP?

  5 layers:
  - Physical
  - Data link/MAC (ARP, SLIP)
  - Network (IP, ICMP, IGMP)
  - Transport (TCP, UDP)
  - Application

    (http, ftp, telnet, smtp)

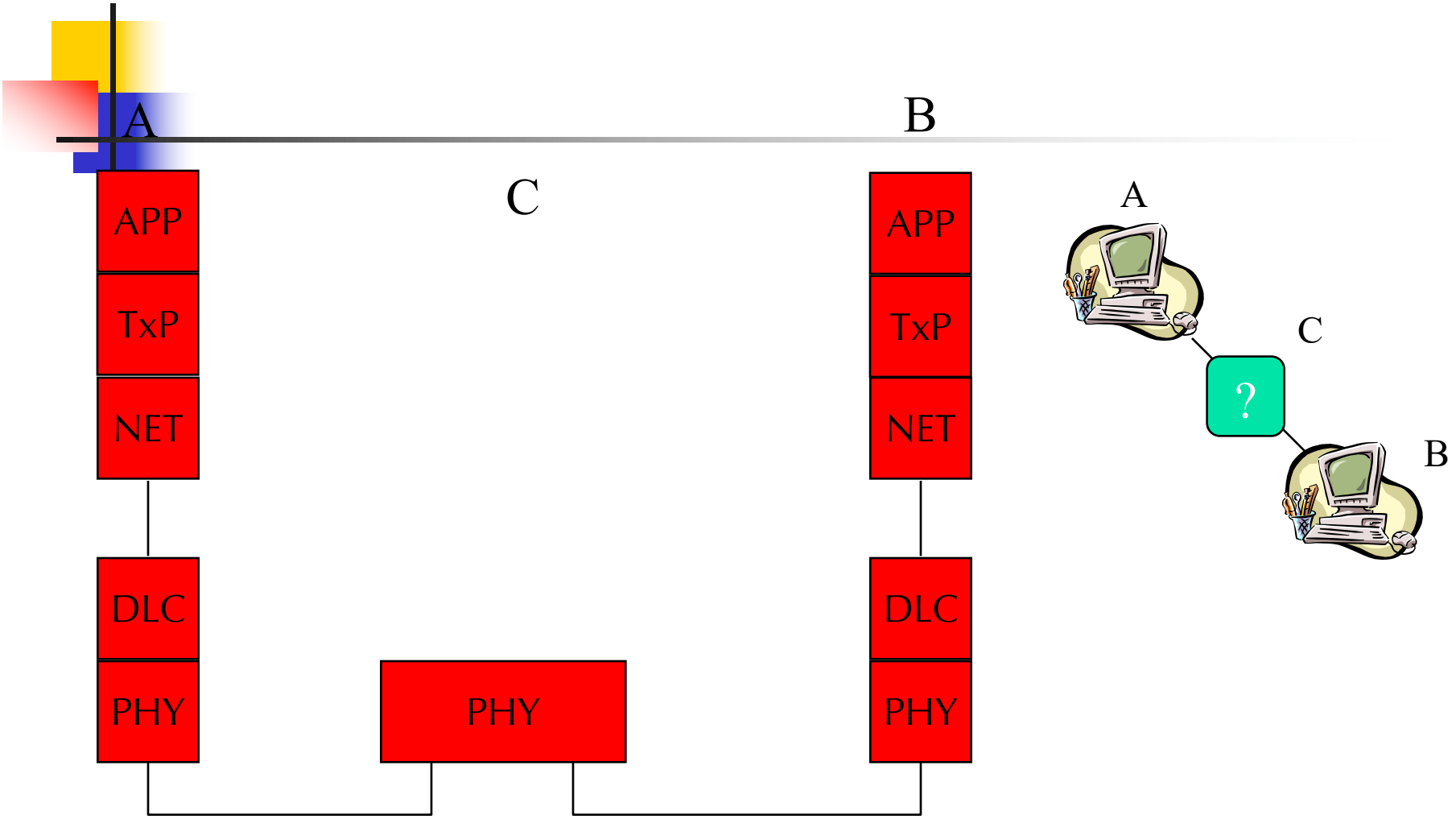




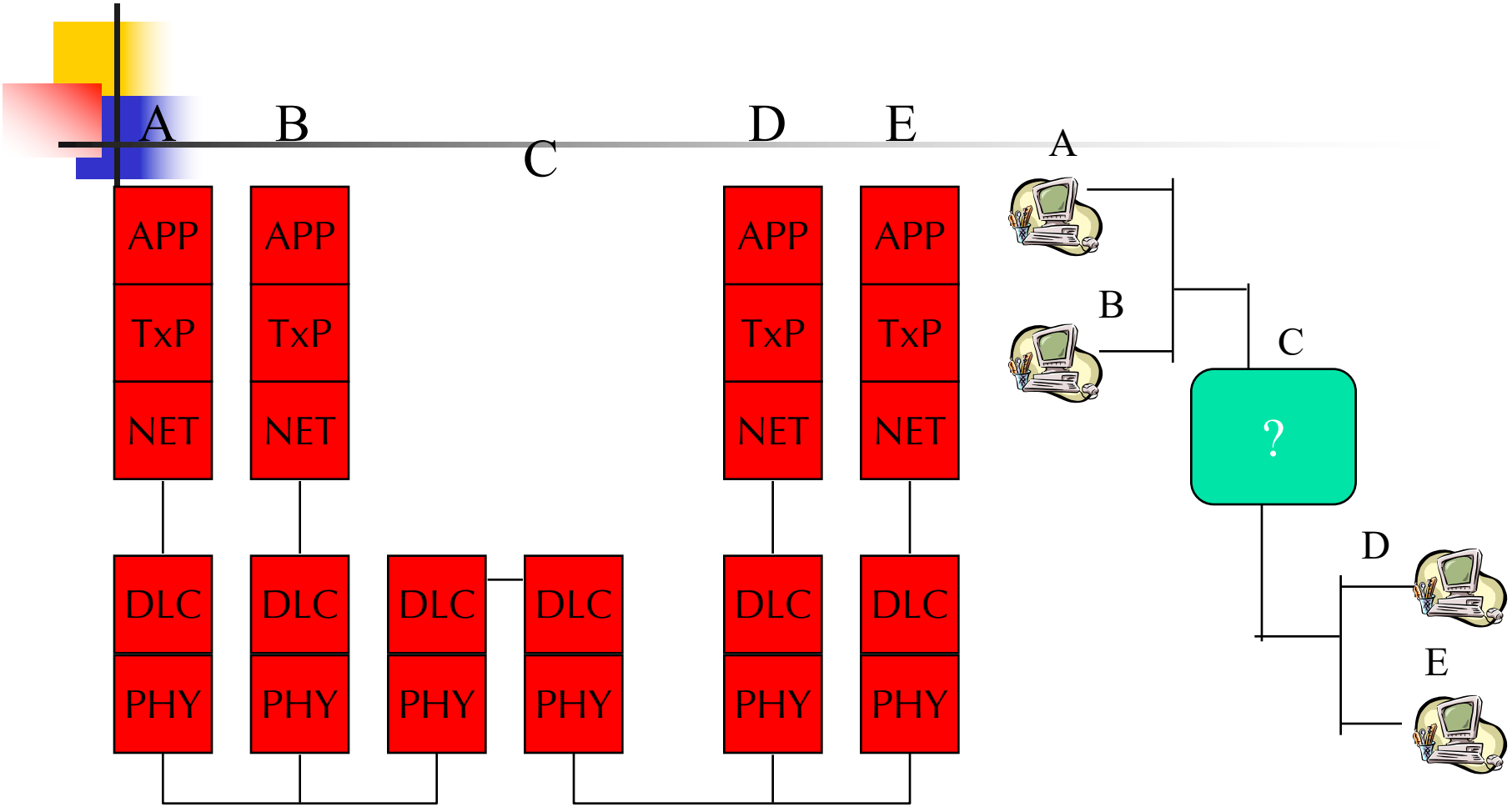


Network Components

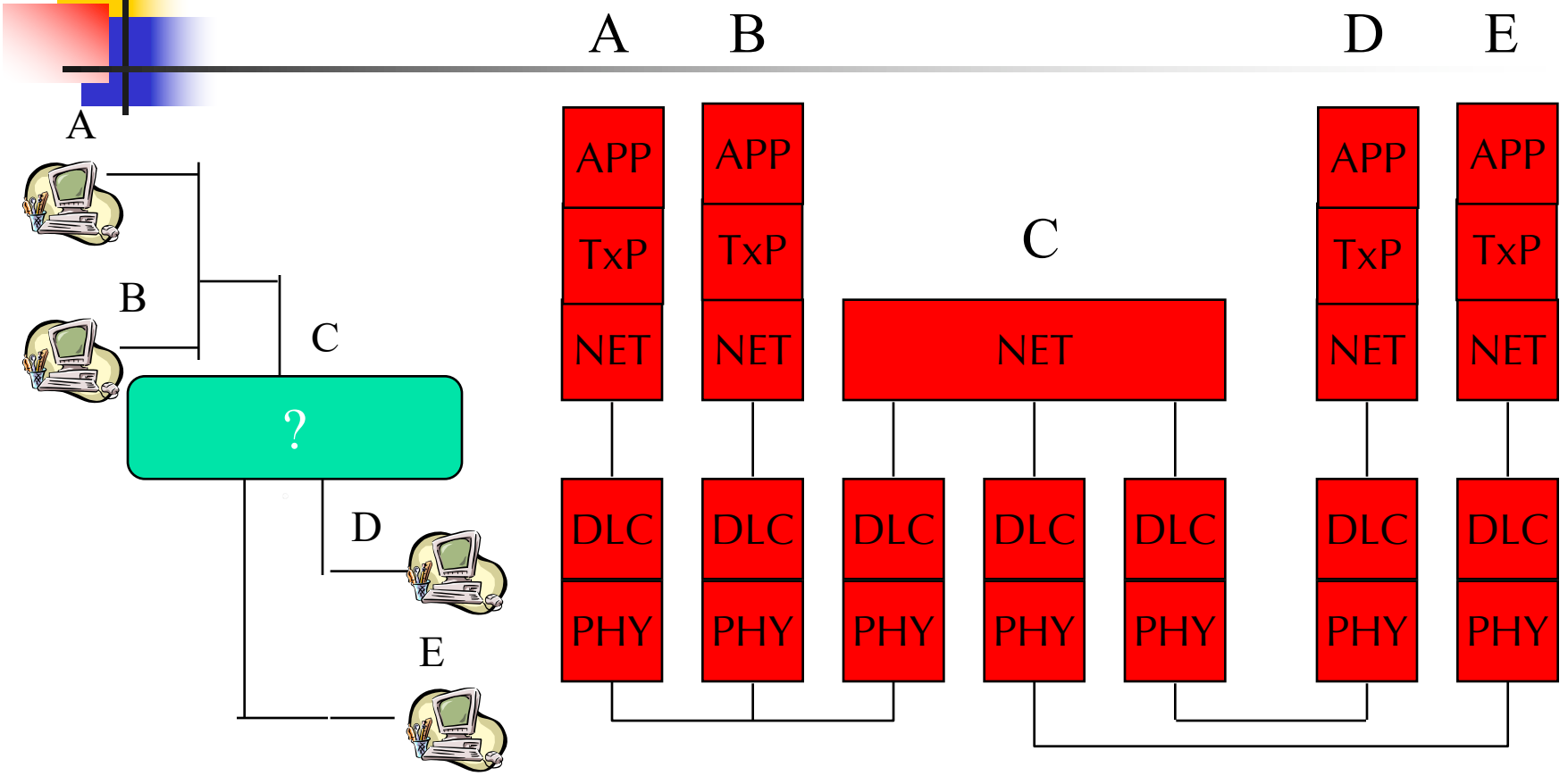
- Different network components/devices function at different layers
  - Embody service at different protocol layers
  - Nomenclature is not very well standardized, and is ever-changing
  - Mixed, "layer-blurring" devices complicate matters
- For each component, designer/implementer is responsible for
  - Completely designing and implementing protocol at that layer
  - Making calls to lower layer
  - Supporting calls from higher layer



Component C in this figure is a *wire, hub, or wireless channel*.

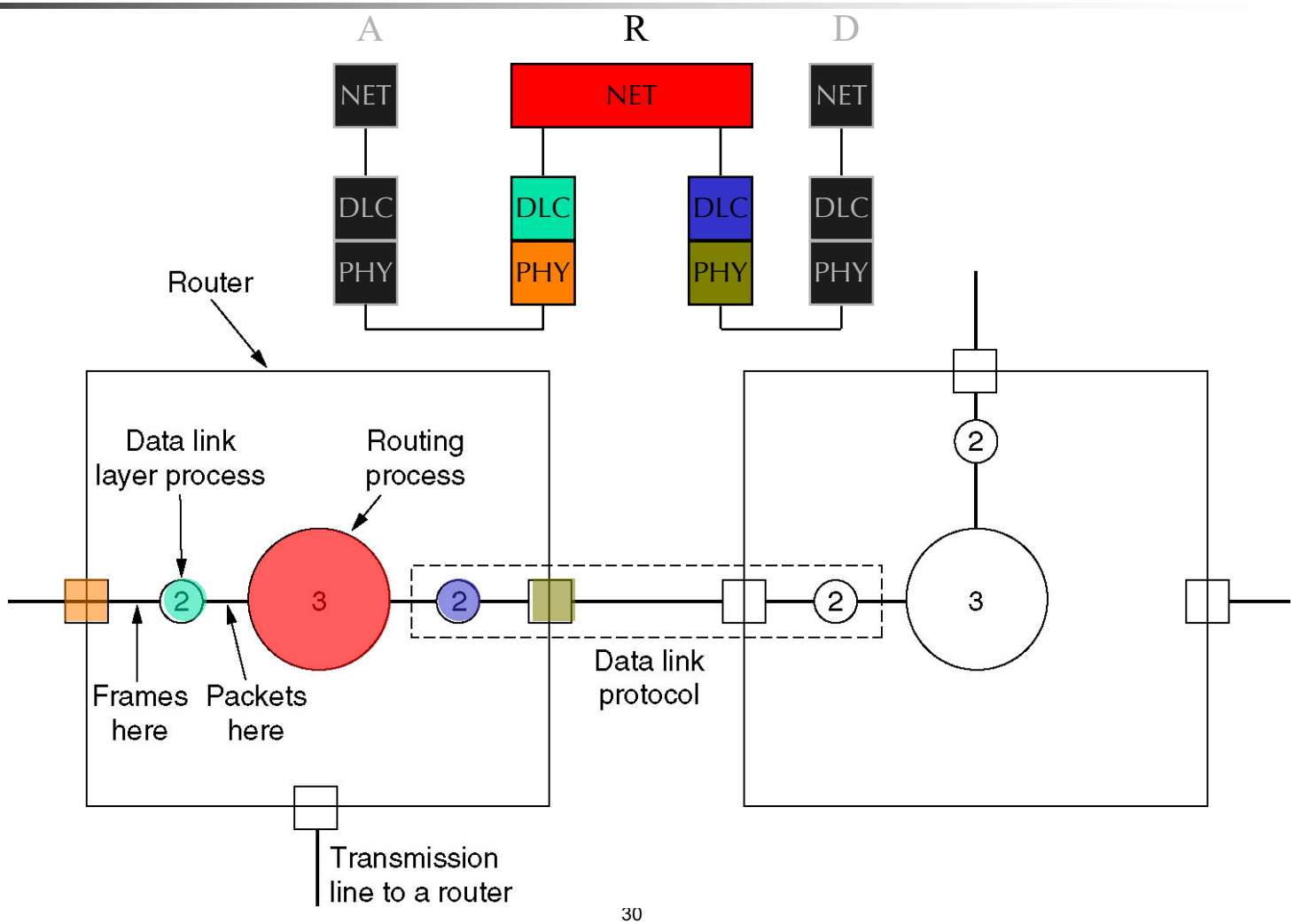


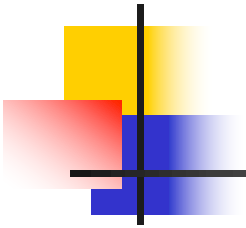
Computer C in this figure is a *switch*.



Computer C in this figure is a *router, or switch*
Computers A, B, D, E are *hosts*

Layers in a Router/Switch



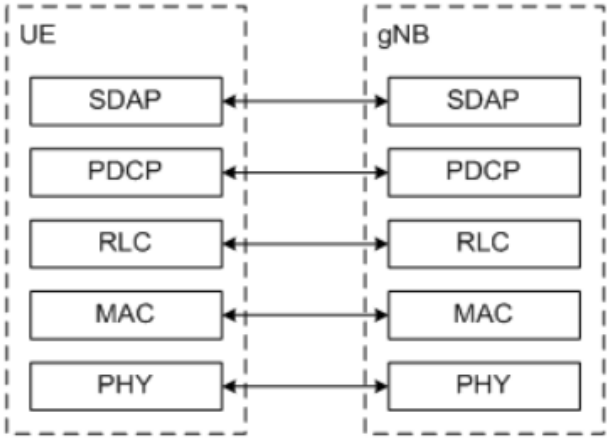


Layering

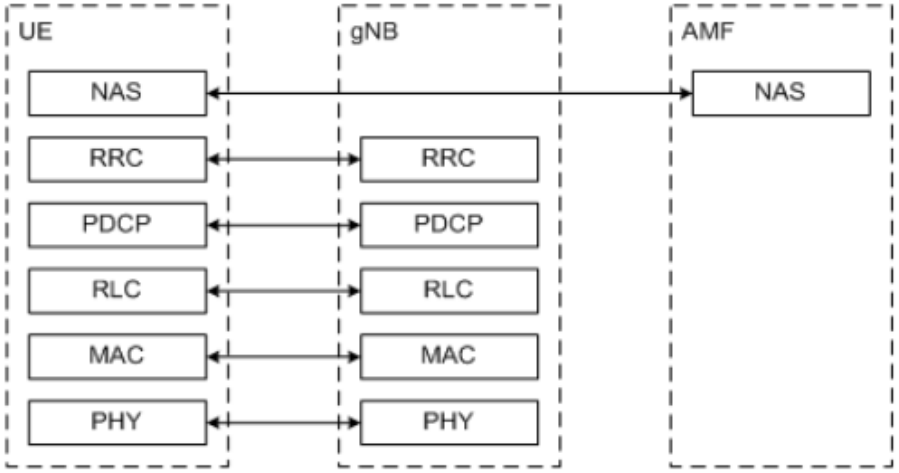
- We have broken a complex problem into smaller, simpler pieces
  - Provides the application with *sophisticated* services
  - Each layer provides a clean abstraction to the layer above
- HOWEVER - sacrifices efficiency
  - Might even sacrifice functionality, or optimality
  - Recently**, cross-layer approaches** have started gaining ground
- In practice, may balance strict layering with practical optimization
  - Power-aware routing in ad-hoc networks

5G Protocol Stack

User plane



Control plane



5G Protocol Stack

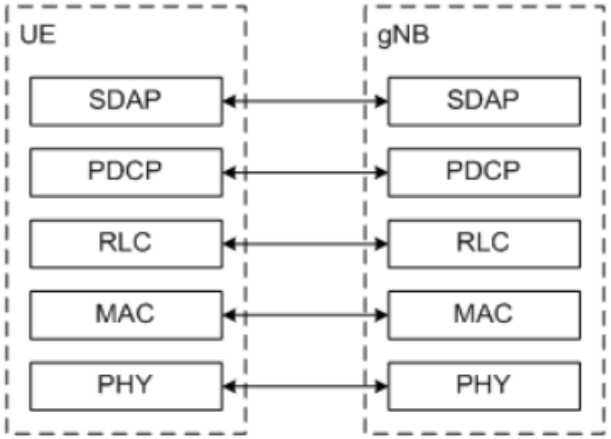
Radio Link Control (RLC) – mac high

- RLC operates in 3 modes of operation: **Transparent Mode (TM), Unacknowledged Mode (UM), and Acknowledged Mode (AM).**

- RLC Layer is responsible for transfer of upper layer PDUs, error correction through ARQ (Only for AM data transfer), Concatenation, segmentation and reassembly of RLC SDUs (Only for UM and AM data transfer).

5G Protocol Stack

User plane



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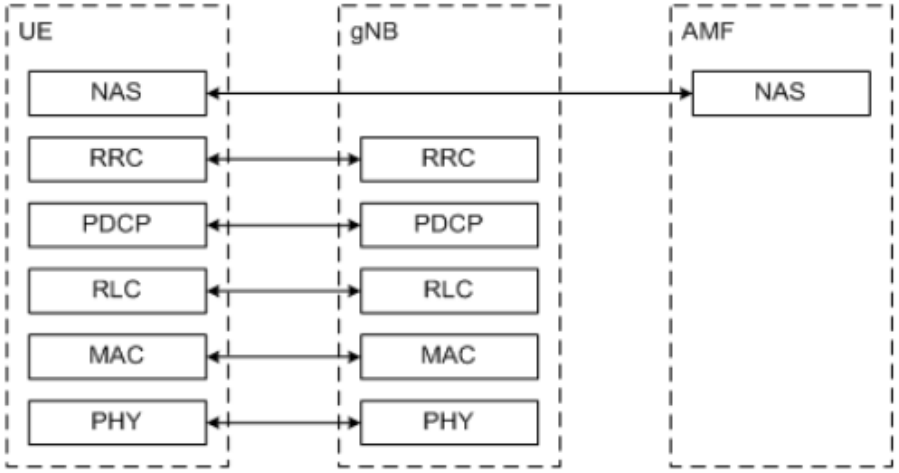
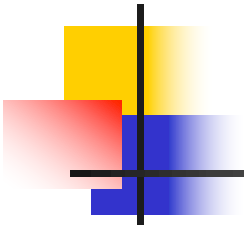




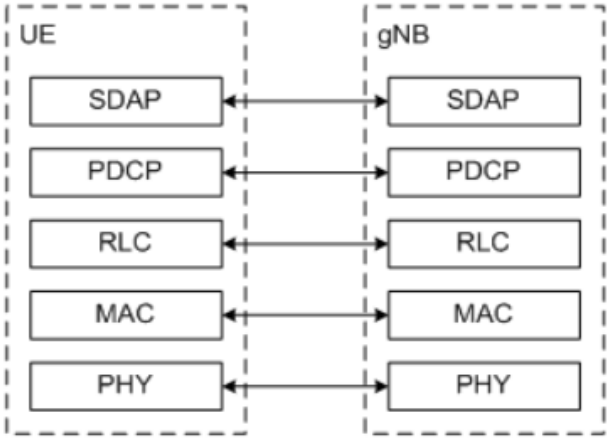
5G Protocol Stack

Packet Data Convergence Control (PDCP)

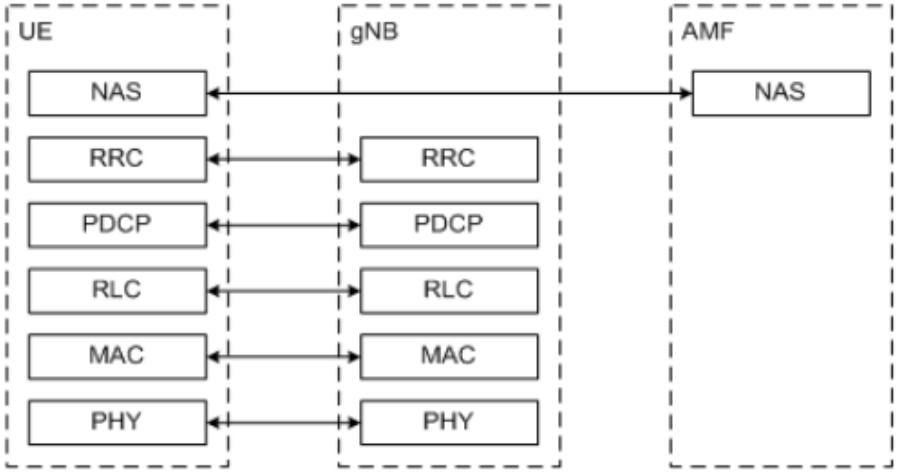
- Header compression and decompression of IP data
- Transfer of data (user plane or control plane)
- Maintenance of PDCP Sequence Numbers (SNs)
- In-sequence delivery of upper layer PDUs at re-establishment of lower layers, Duplicate elimination of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on RLC AM

5G Protocol Stack

User plane



Control plane



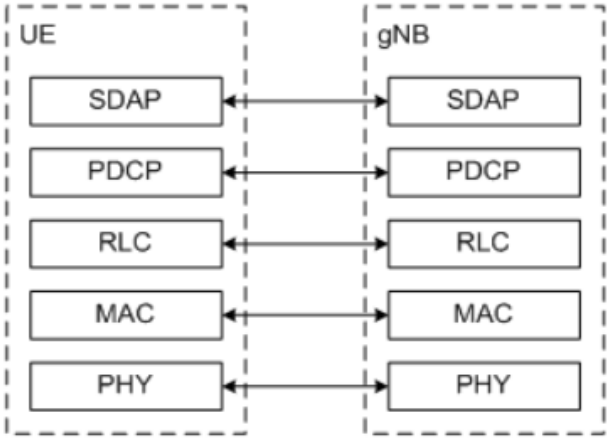
5G Protocol Stack

Service Data Adaptation Protocol

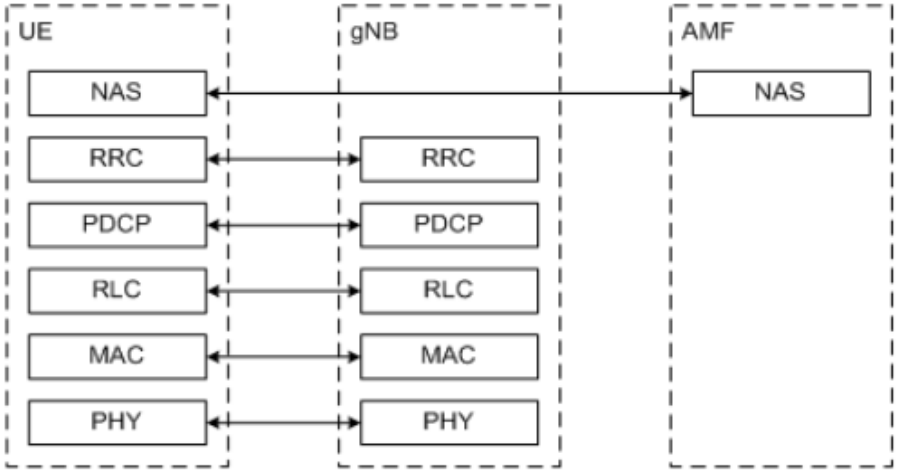
- QoS Flow handling across the 5G air interface.
- Ensure that the packet receives the correct forwarding treatment as it traverses the 5G System

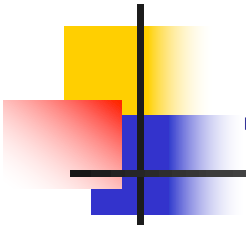
5G Protocol Stack

User plane



Control plane





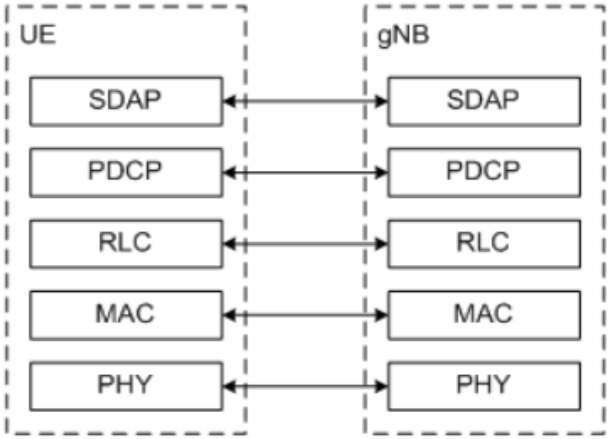
5G Protocol Stack

Radio Resource Control (RRC)

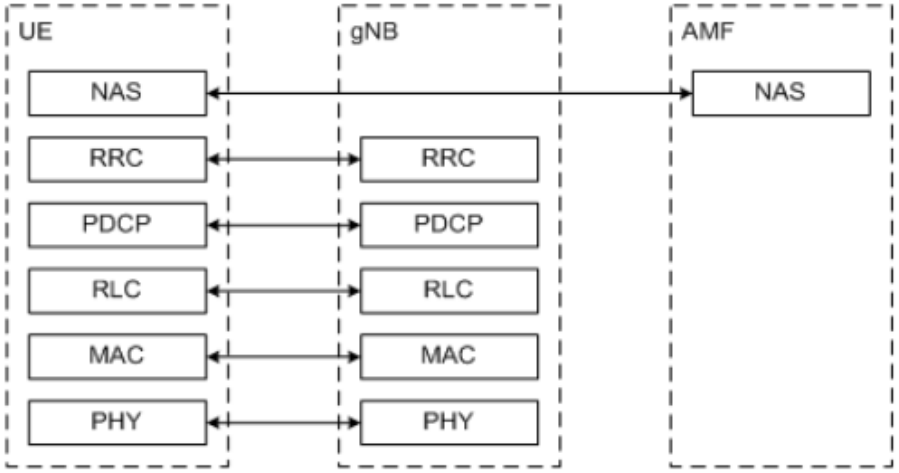
- Broadcast of System Information related to upper layers
- Paging, establishment, maintenance and release of an RRC connection between the UE and RAN
- Security functions including key management, establishment, configuration, maintenance and release of point to point Radio Bearers.

5G Protocol Stack

User plane



Control plane

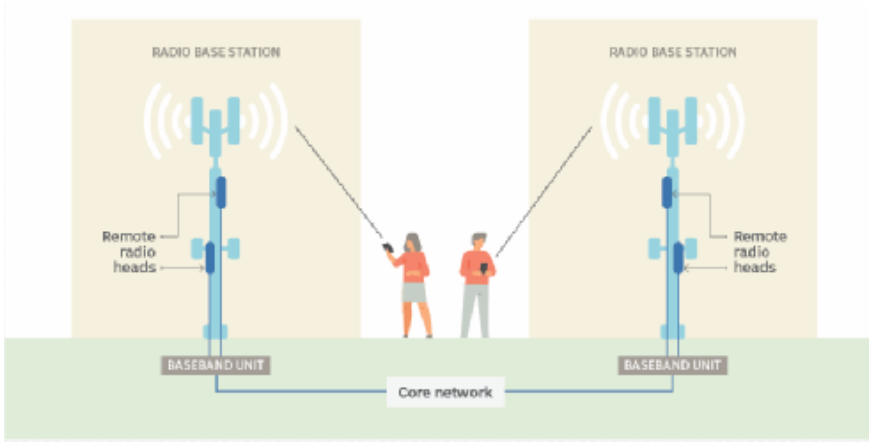


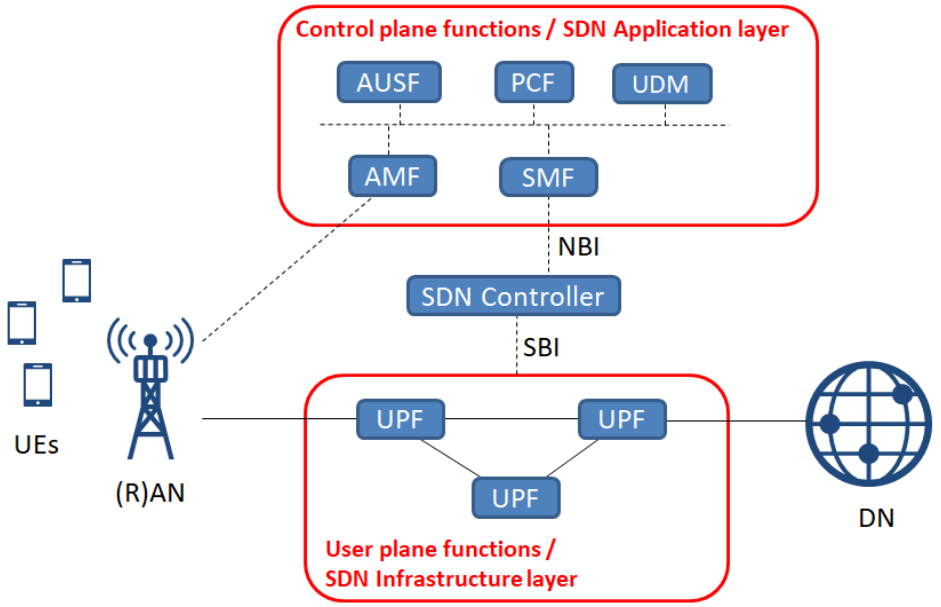
5G Protocol Stack

Non Access Stratum (NAS)

- Form the highest stratum of the control plane between the user equipment (UE) and mobility management entity (MME).
- Support the mobility of the UE and the session management procedures to establish and maintain IP connectivity between the UE and a gateway.

5G Core





- Access & Mobility Management Function (AMF): **registration management, connection management, mobility management, handover**
- Authentication Server Function (AUSF): Manages authentication confirmation timeout
- Unified Data Management (UDM): It **generates authentication credentials used during the authentication process**. It authorizes network access and roaming based on user subscriptions.

NextG Network Invention Area

(figure from Qualcomm)

For more capacity, new use cases and deployments

For IoT wearables, sensors, etc.

For better QoE & system efficiency

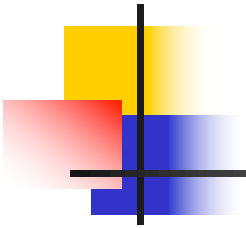
For ubiquitous coverage

For more efficient deployments

Flexible

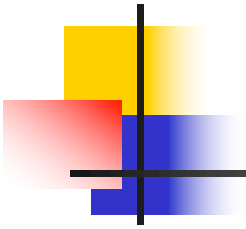
Application-oriented

https://www.3gpp.org/release-17



Running Summary

- Networking is complicated!
- Need to decompose into layers
- Devices can specialize in layer(s), to optimize cost and performance
- This introduces need for further functionality, which can also be considered decomposition (coming up – soon, but not next)



Next Lecture

1. Network Performance and Design