Network Layer

COMP90007 Internet Technologies

Lecturer: Ling Luo

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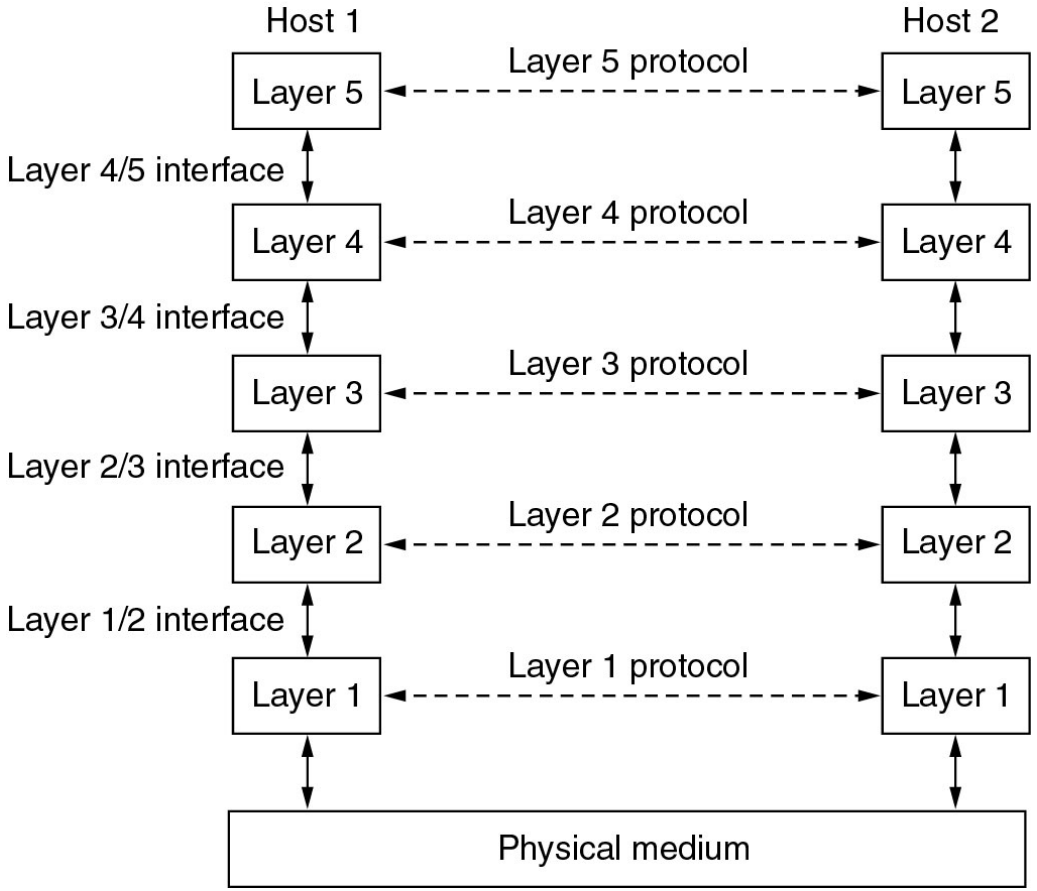
Network Layer

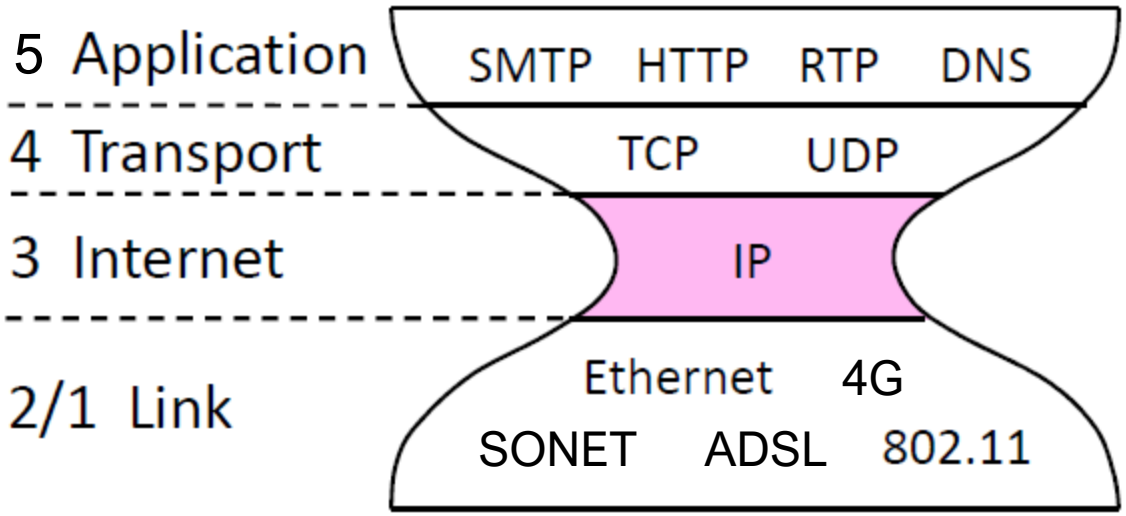
Connecting different networks (internetworking)

Framing, error and flow control, MAC

Different cables, wireless, signal, digital to analogue

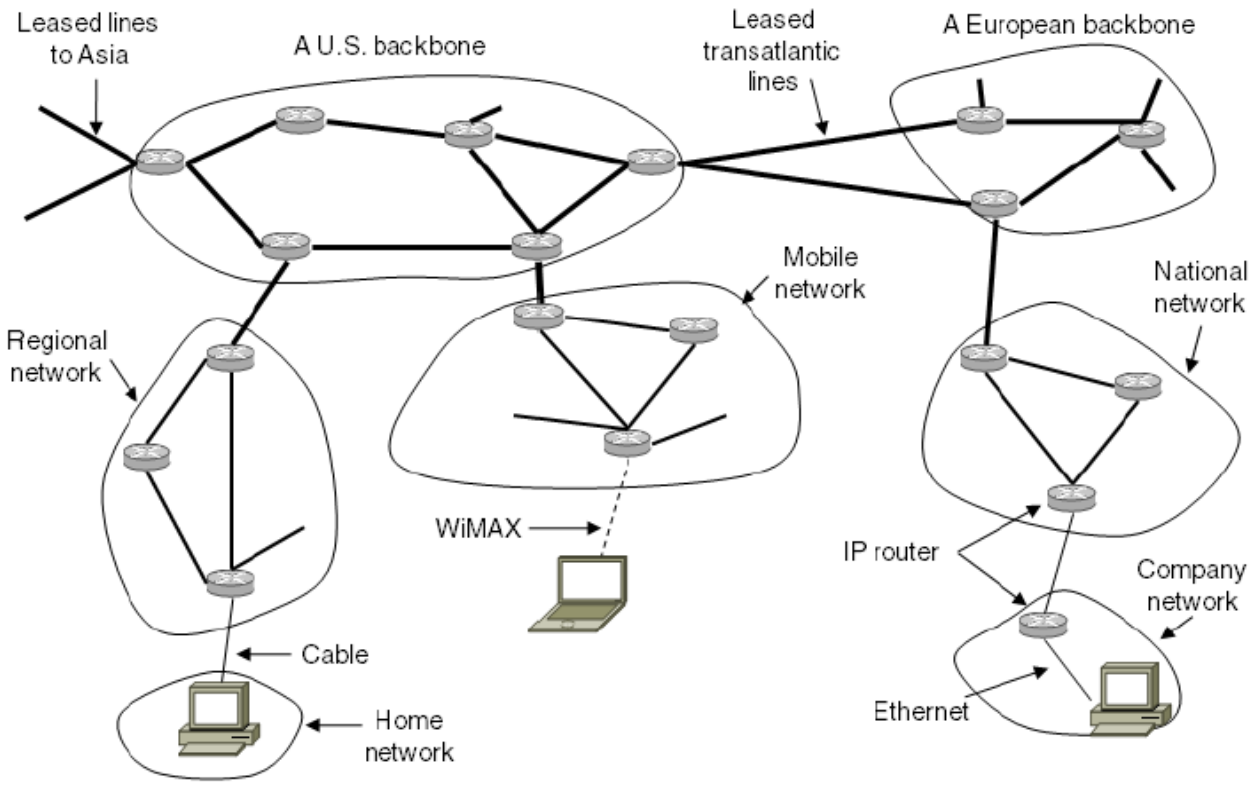


Internet

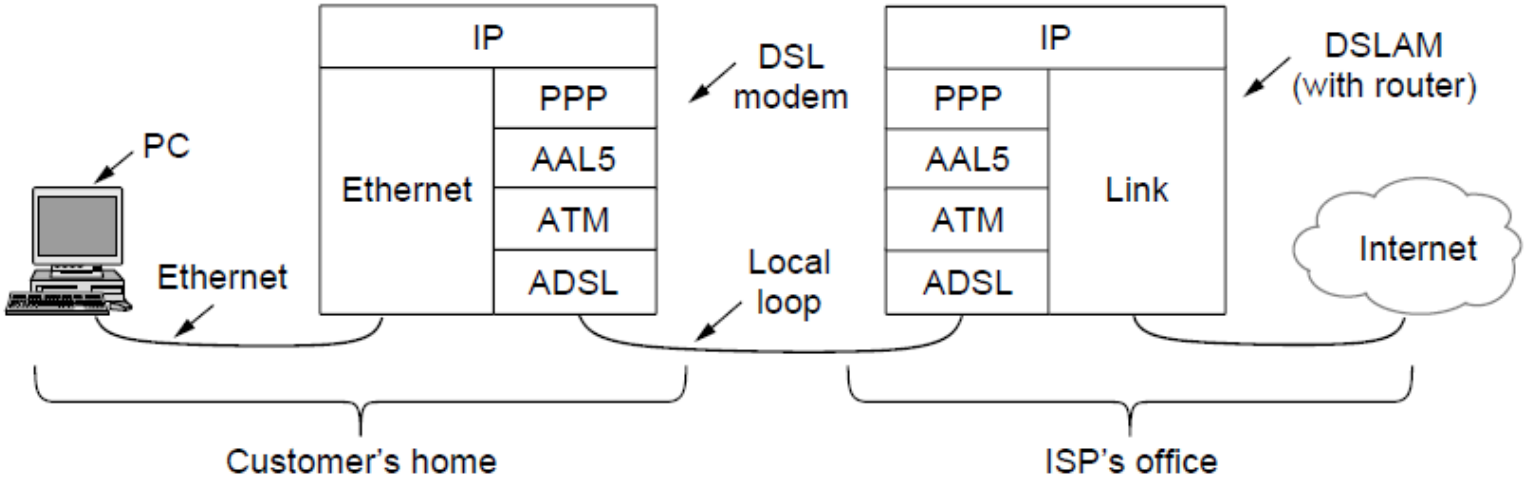

5 Application
SMTP HTTP RTP DNS
4 Transport
TCP UDP
3 Internet
IP
2/1 Link
Ethernet 4G
SONET ADSL 802.11

Network Layer in the Internet (1)

- Internet is a collection of many networks that is interconnected by the IP protocol



Network Layer in the Internet (2)

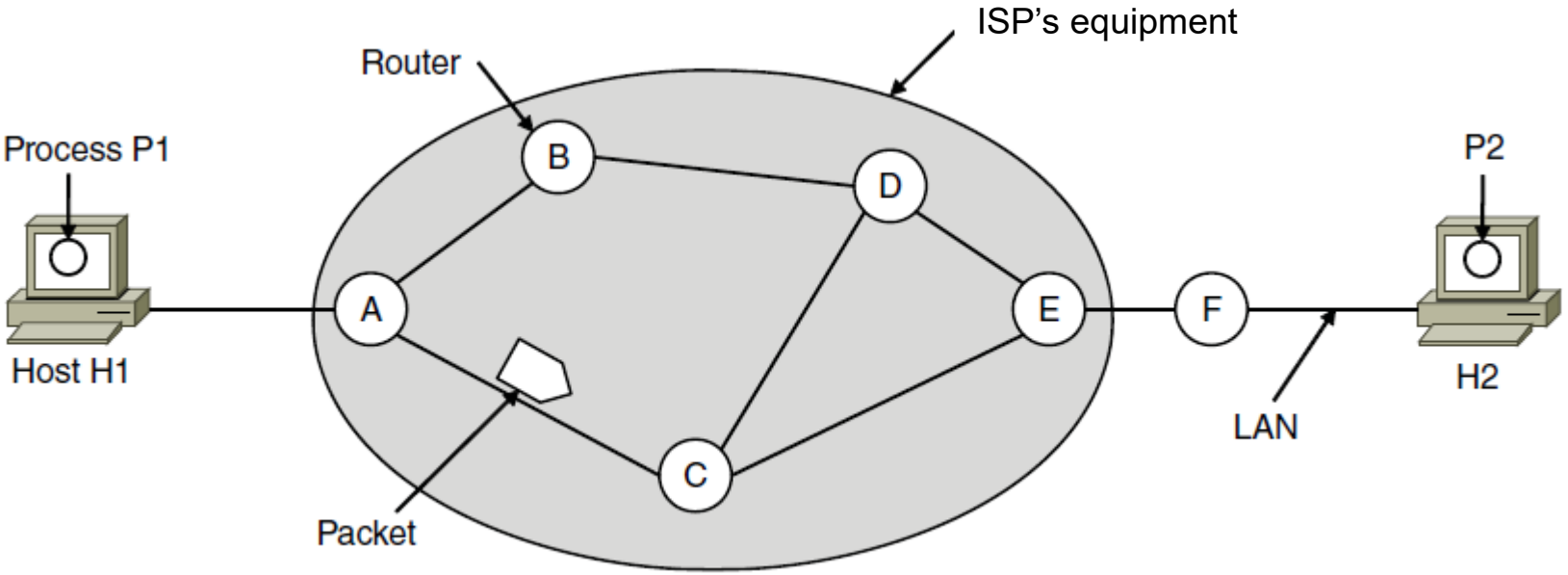


Internet Protocol (IP)

- The network layer protocol IP holds the whole Internet together.
- Provides a **best-effort** service to route datagrams from source host to destination host
- These hosts may be
  - On the same network
  - On different networks

Store-and-Forward Packet Switching

- Hosts generate packets and inject into the network
- Routers treat packets as messages, receiving/storing them and then forwarding them based on how the message is addressed
- **Router routes packets through the network**



Services Provided to the Transport Layer

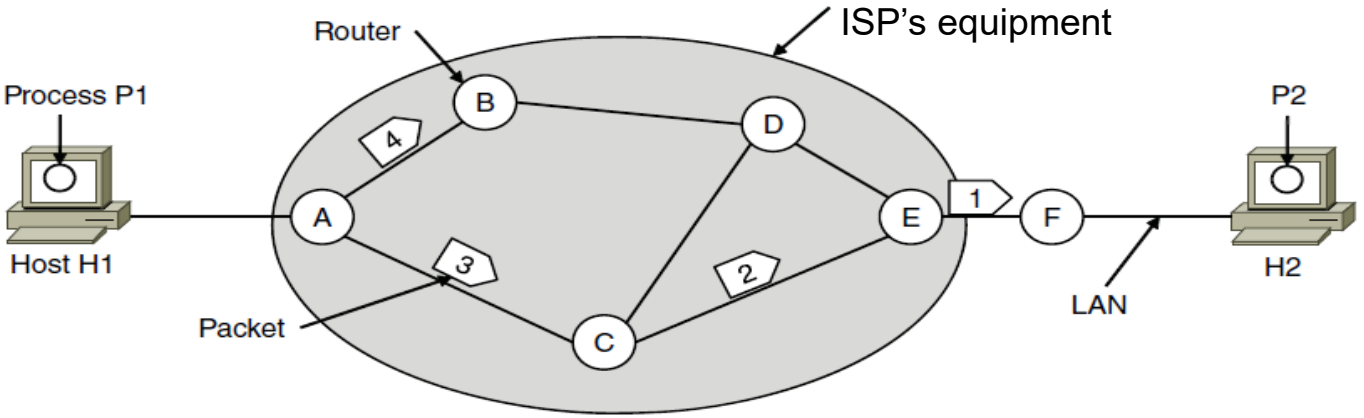
- Design goals:
  - Services should be **independent of router technologies**
  - Transport layer should be shielded from number, type and topology of routers
  - Network addressing should use a uniform numbering plan (network identifier)

Types of Services

- **Connectionless**: Packets (datagrams) are injected into subnet **individually** and routed **independently** to destination
  - Internet: move packets in a potentially unreliable subnet; QoS is not easily implemented
  - Flow and error control done by other layers
- **Connection-oriented**: Packets travelling between destinations, following the **same route**
  - Telecommunication: guarantee reliability; QoS is important

Routing within a Datagram Subnet

- **Connectionless - post office model**: packets are routed individually based on destination addresses in them
- Packets can take different paths
- E.g., P1 sends a long message to P2



A's table (initially)

A	
B	B
C	C
D	B
E	C
F	C

Dest. Line

A's table (later)

A	
B	B
C	C
D	B
E	B
F	B

C's Table

A	A
B	A
C	
D	E
E	E
F	E

E's Table

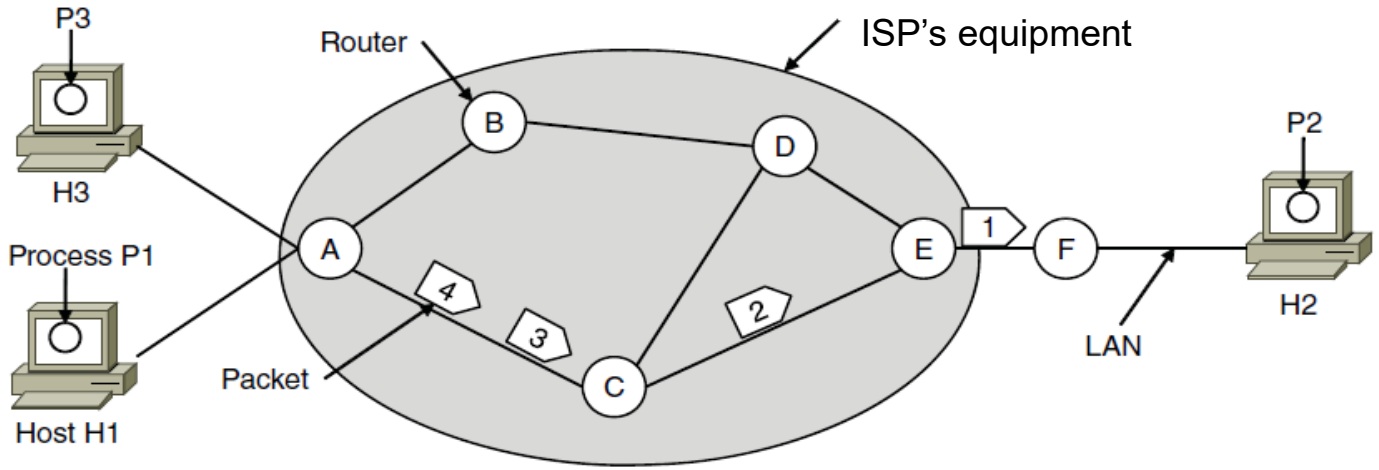
A	C
B	D
C	C
D	D
E	
F	F

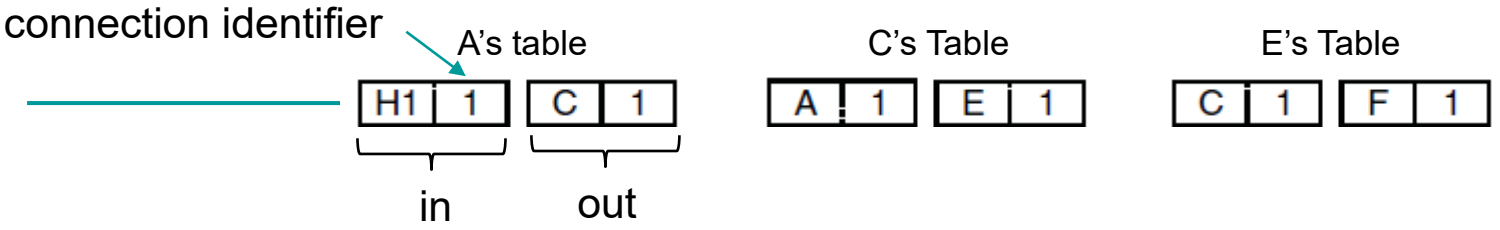
Routing table (can be fixed or change over time)

Routing algorithm – manages the routing table

Routing within a Virtual-Circuit Subnet

- **Connection-oriented - telephone network model:** Packets are routed through virtual circuits (created earlier) based on tag number (not full address but unique at a given link) in them
  - Packets take the same path to avoid having to choose a new route for every packet
  - e.g., MultiProtocol Label Switching Network





Datagram vs. Virtual-Circuit Subnets

Issue	Datagram network	Virtual-circuit network
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Compromises in VC and Datagram Subnets (1)

- Setup time vs. address parsing time
  - VC: requires setup time and resources, but packet transmission is very fast after that
  - Datagram: more complicated lookup procedure
- Memory of router
  - VC: requires entry per virtual circuit
  - Datagram: requires large tables of every possible destination route
- Bandwidth
  - VC: saves potential overhead in full addressing of each packet and computation of path. Still needs them during setup
  - Datagram: full destination address in every packet

Compromises in VC and Datagram Subnets (2)

- QoS and congestion avoidance
  - VC: easier to provide QoS, able to reserve CPU, bandwidth and buffer in advance
- Longevity
  - VC: can be setup for repeating and long-running uses e.g. Permanent VC's
- Vulnerability
  - VC: particularly vulnerable to hardware/software crashes, all VC's aborted and no traffic until they are rebuilt
  - Datagram: can use an alternative route

Different Networks

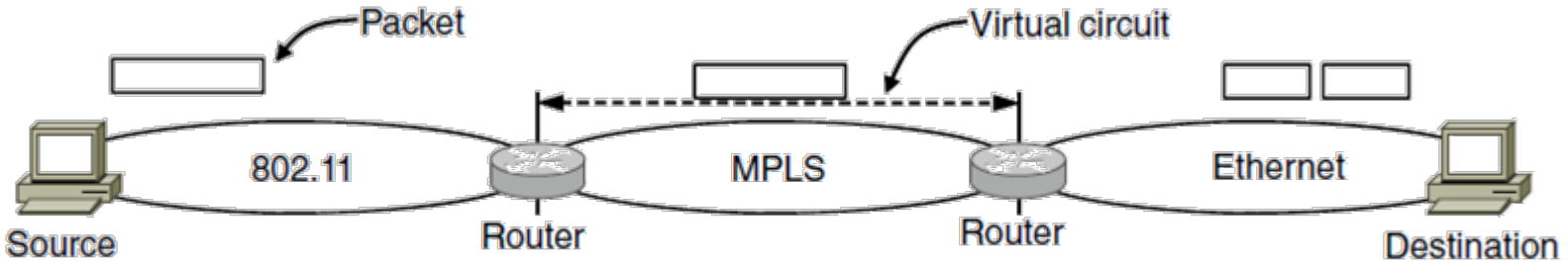
- Service offered: connectionless vs. connection-oriented
- Packet size: different max
- Addressing: different sizes, flat or hierarchical
- Quality of service: present or absent
- Reliability: different levels of loss
- Security: privacy rules, encryption
- Parameters: different timeouts

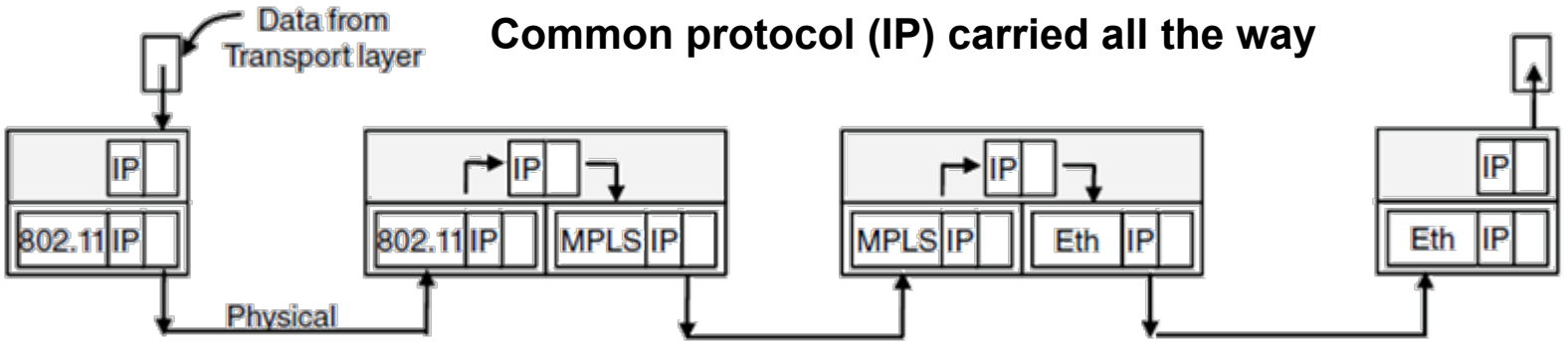
Internetworking

- Internetworking joins multiple, different networks into a single larger network
- Issues when connecting networks:
  - Different network types and protocols
  - Different motivations for network choices
  - Different technologies at both hardware and software levels

How Different Networks are Connected

- Internetworking based on a common network layer – IP





Tunneling

- Tunneling is a special case used when the source and destination are on the same network, but there is a different network in between.
  - Source packets are encapsulated in packets, travelling through connecting network

Tunneling IPv6 Packets through IPv4