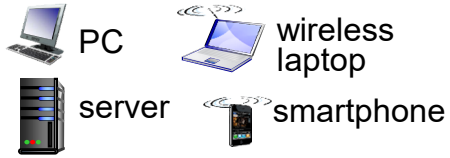
Computer Network and Internet

Contents

- What is the Internet?
- Network edge
  - ✓ End system, Access networks, Links
- Network core
  - ✓ Packet switching, Circuit switching, Network structure
- Performance
  - ✓ Delay, loss, throughput
- Protocol layers, Service models
  - ✓ IP protocol stack & OSI 7 layers

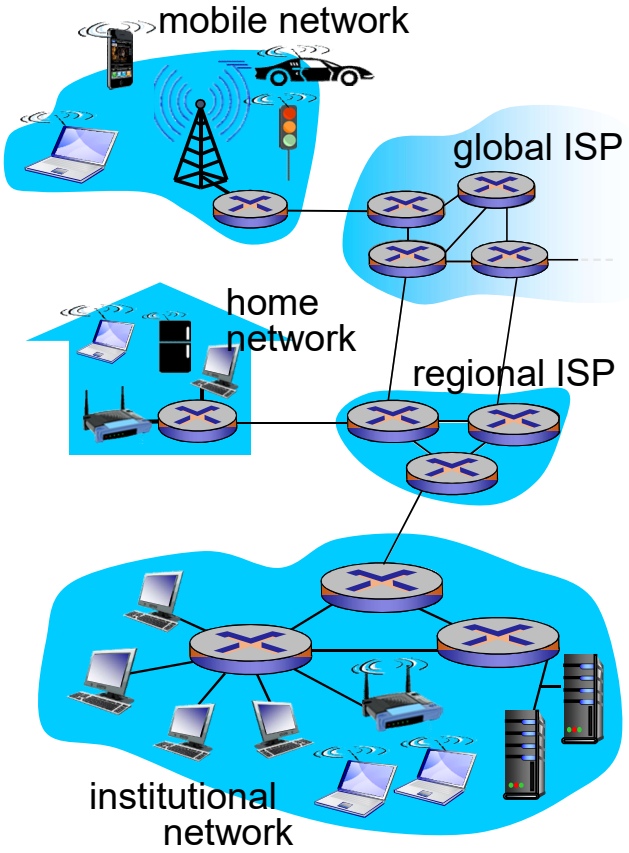
What is the Internet?: 구성 요소 관점

- 디바이스 (connected devices)
  - ✓ hosts = end systems
  - ✓ network apps 사용



- 통신 링크 (communication links)
  - ✓ 데이터 전송을 위한 매체

- 패킷 스위칭 (packet switches)
  - ✓ 데이터 패킷의 전송(forward packets)
  - ✓ 라우터와 스위칭 장비 사용

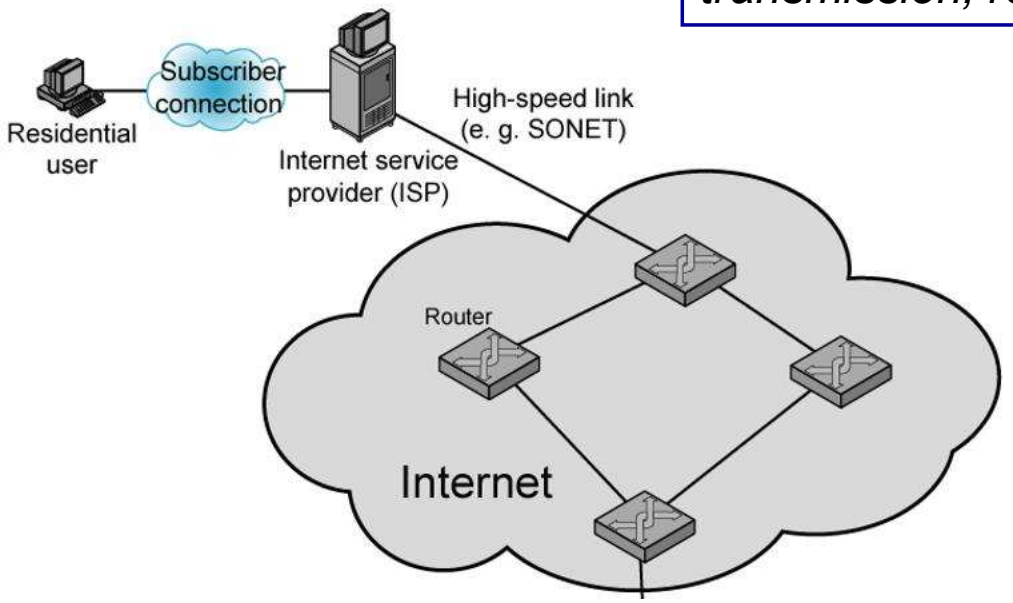


What is the Internet?: 구성 요소 관점

- 인터넷: 네트워크들의 네트워크
  - ✓ Internet is a network of networks

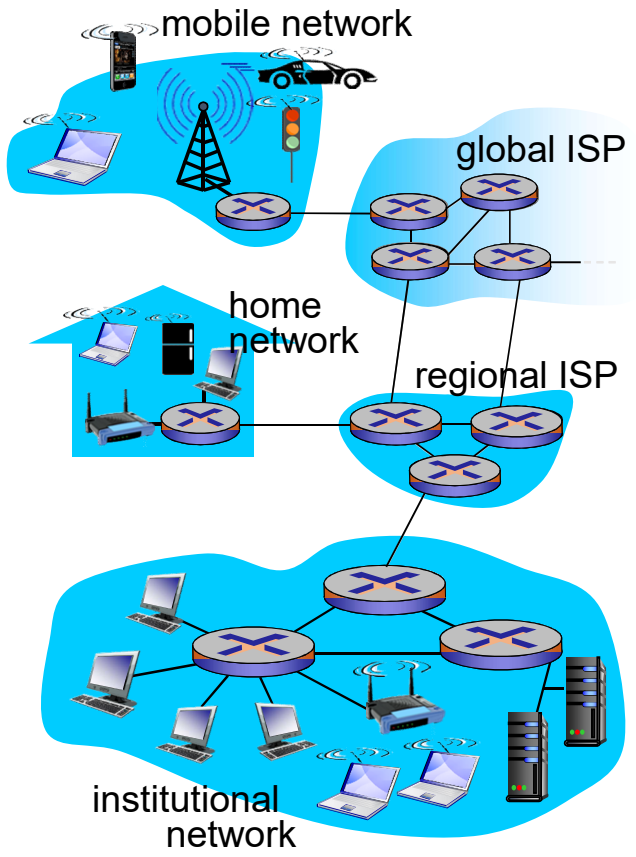
- 프로토콜 (protocol)
  - ✓ 통신규약
  - ✓ 데이터 메시지의 송신 및 수신 제어

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



What is the Internet?: 구성 요소 관점

- 애플리케이션에 서비스를 제공하는 인프라스트럭쳐
  - ✓ infrastructure that provides services to applications:
    - ➢ Web, email, games, e-commerce, etc.
- 애플리케이션에 프로그래밍 인터페이스를 제공
  - ✓ provides programming interface to apps
    - ➢ 인터넷에 연결하여 애플리케이션의 송신 및 수신을 허용함



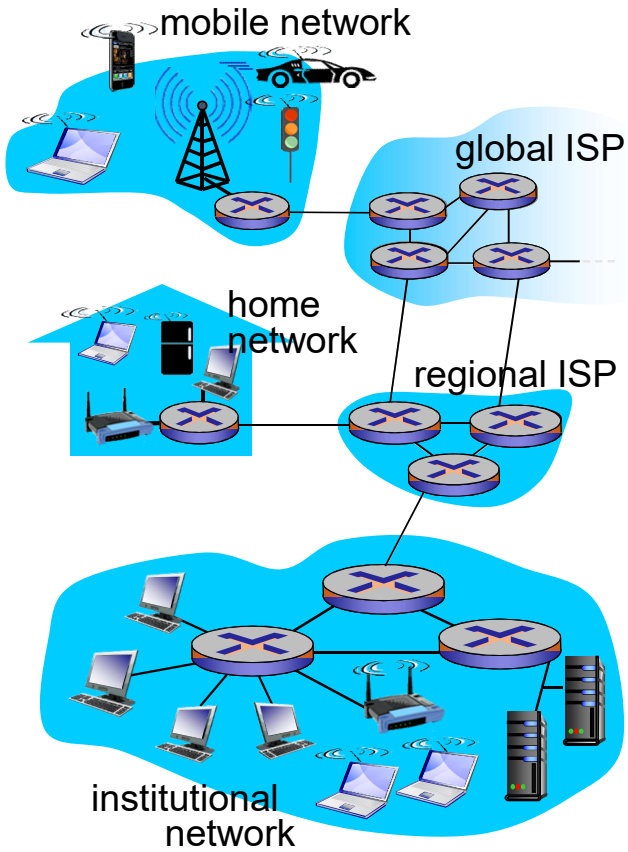
Network Edge – Network Architecture

- 네트워크 엣지 (Network edge)
  - ✓ 호스트(hosts): clients and servers
  - ✓ servers often in data centers

- 액세스 네트워크 및 물리 매체

  (Access networks, physical media)
  - ✓ 유무선 통신링크
  - ✓ wired and wireless communication links

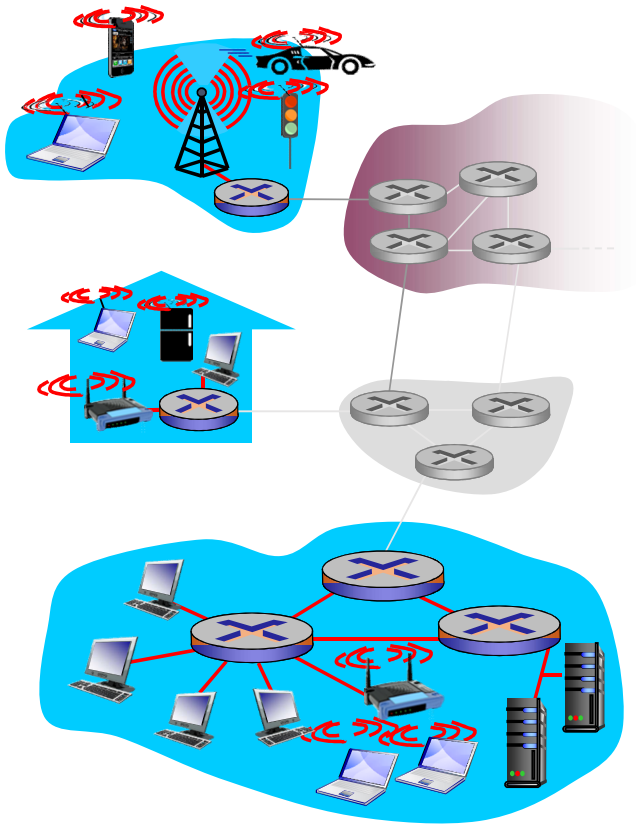
- 네트워크 코어 (Network core)
  - ✓ 네트워크들의 네트워크
  - ✓ a network of networks
  - ✓ 라우터들로 연결된 네트워크



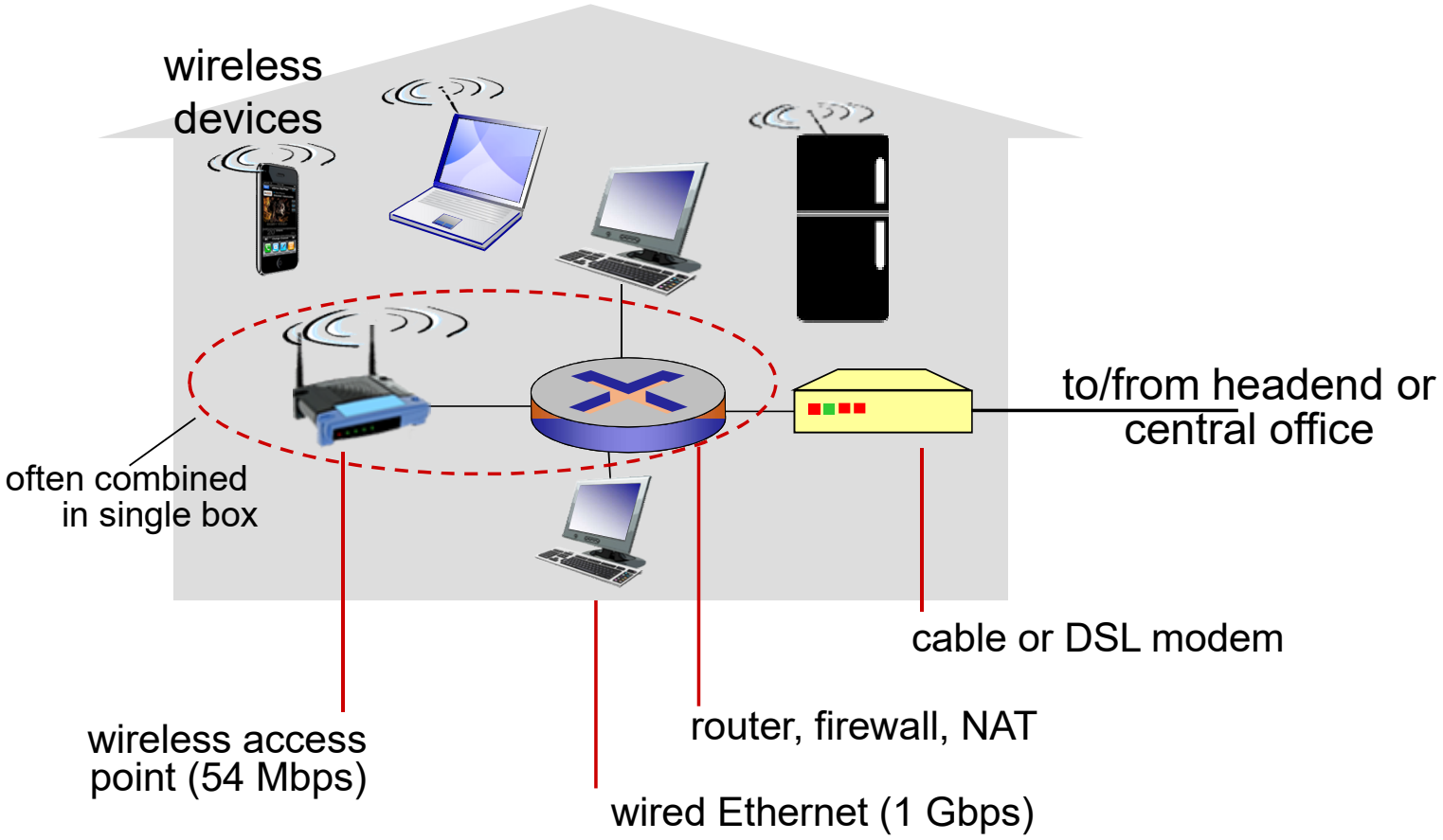
Access networks

- Q: How to connect end systems to edge router?
  - ✓ 가정 네트워크 (Residential access network)
  - ✓ 기관 네트워크 (Institutional access network)
  - ✓ 이동 네트워크 (Mobile access network)

- Keep in mind:
  - ✓ 액세스 네트워크의 대역폭이란? (Bandwidth (bits per second) of access network?)
  - ✓ Shared or dedicated?



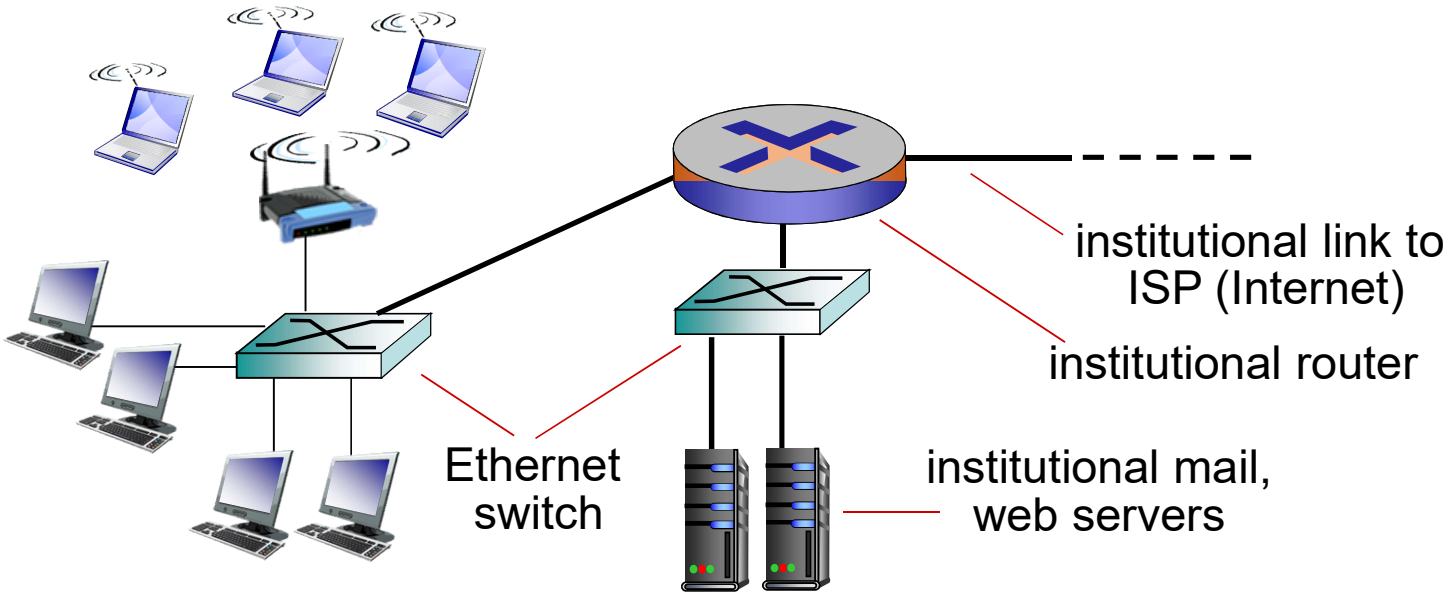
Access network: Home



Access network: Enterprise

- 회사 및 대학과 같은 기관에서 주로 사용
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps
- 최근 end system은 이더넷 스위치에 연결됨

  (today, end systems typically connect into Ethernet switch)



Access network: Wireless

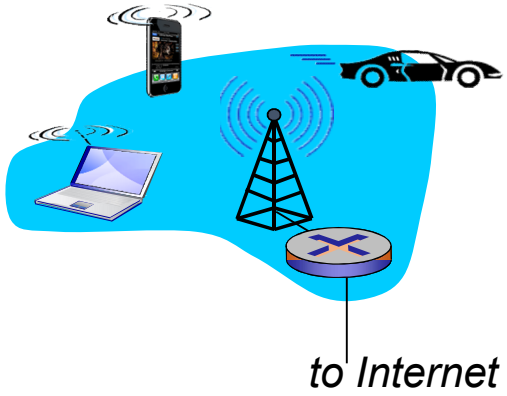
- 공유된 무선 액세스 네트워크를 통해 end system이 라우터와 연결 (shared wireless access network connects end system to router)
  - ✓ via base station aka "access point"

wireless LANs:

- within building (100 ft.)
- 802.11b/g/n/ac (WiFi): 11, 54, 450 Mbps transmission rate

wide-area wireless access

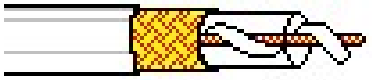
- provided by telco (cellular) operator, 10' s km
- between 1 and 10 Mbps
- 3G, 4G: LTE



Physical media

- Twisted pair (꼬임 쌍선)
  - ✓ two insulated copper wires
    - ➢ Category 5: 100 Mbps, 1 Gbps Ethernet
    - ➢ Category 6: 10Gbps

- Coaxial cable (동축 케이블)
  - ✓ two concentric copper conductors
  - ✓ bidirectional
  - ✓ broadband:
    - ➢ multiple channels on cable



- Fiber optic cable (광 케이블)
  - ✓ glass fiber carrying light pulses, each pulse a bit
  - ✓ high-speed operation
  - ✓ Low error rate

Physical media – radio

- 전자기장을 이용한 신호 전달
  (signal carried in electromagnetic spectrum)
- 유선을 쓰지 않음 (no physical "wire")
- 양방향 (bidirectional)
- 전파 환경 (propagation environment effects):
  - ✓ 반사 (reflection)
  - ✓ 장애 (obstruction by objects)
  - ✓ 간섭 (Interference)

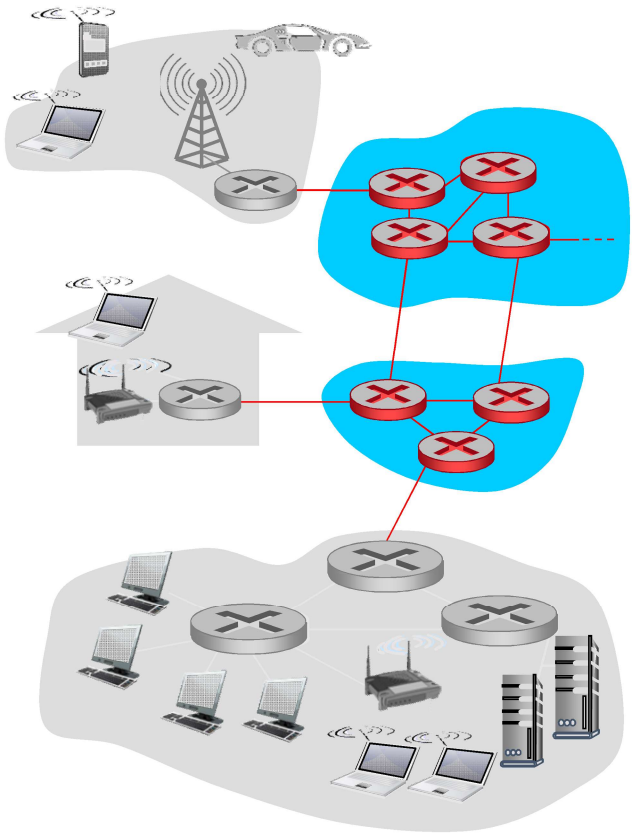
- Radio link types:
  - ✓ Terrestrial Microwave
  - ✓ LAN
  - ✓ Cellular
  - ✓ Satellite

Network Core

- 라우터로 구성된 망

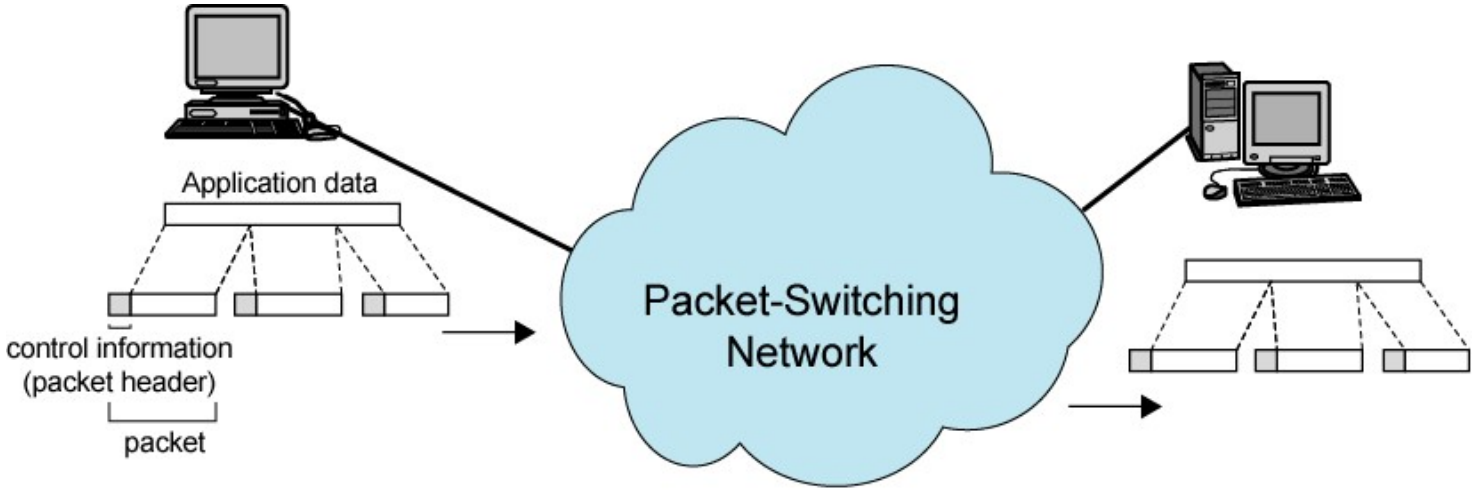
  (Mesh of interconnected routers)

- Packet-switching
  - ✓ 애플리케이션 계층 메시지를 패킷으로 분리
  - ✓ 소스 노드에서 목적지 노드까지 라우터를 경유하여 패킷 전송
  - ✓ 각각의 패킷이 전체 링크 용량을 사용하며 전송



Packet Switching

- 데이터를 패킷으로 분리하여 전송



Packet Switching

- 라우터를 경유하여 패킷 단위 전송

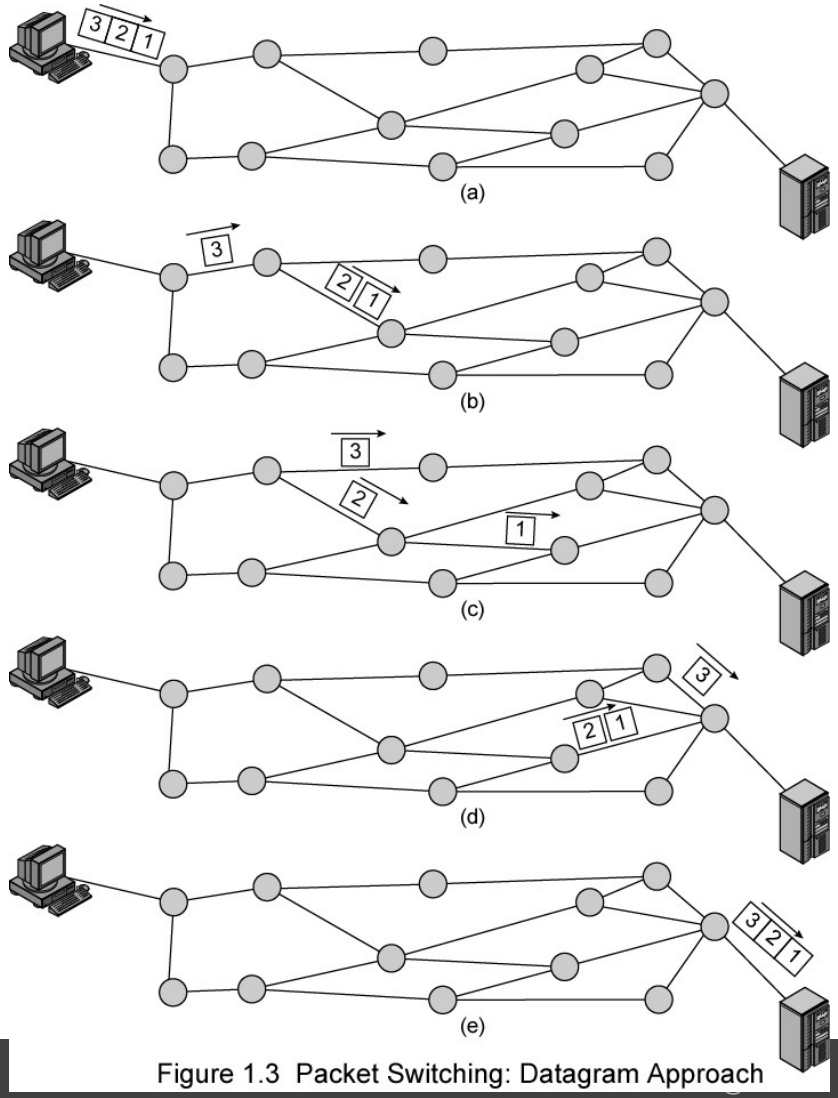
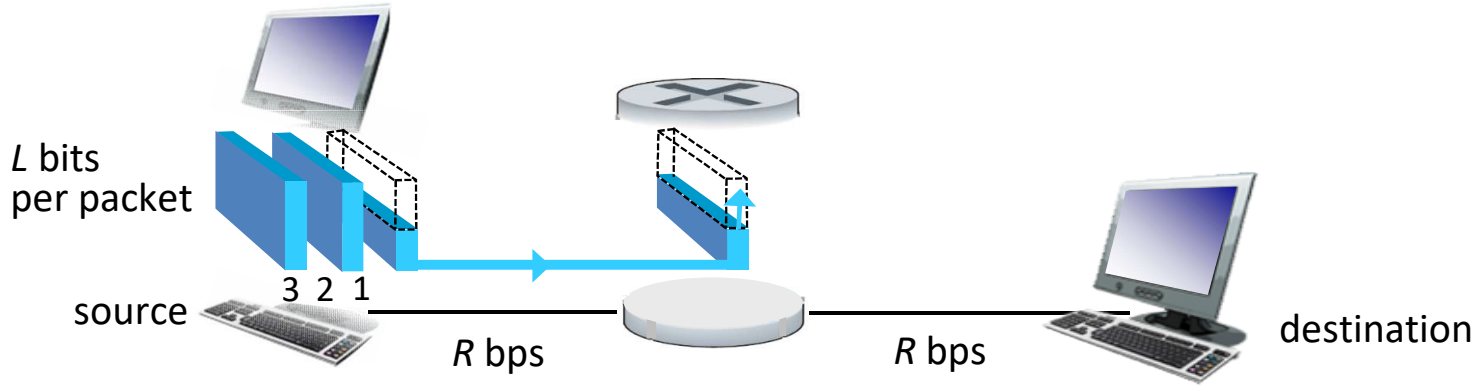


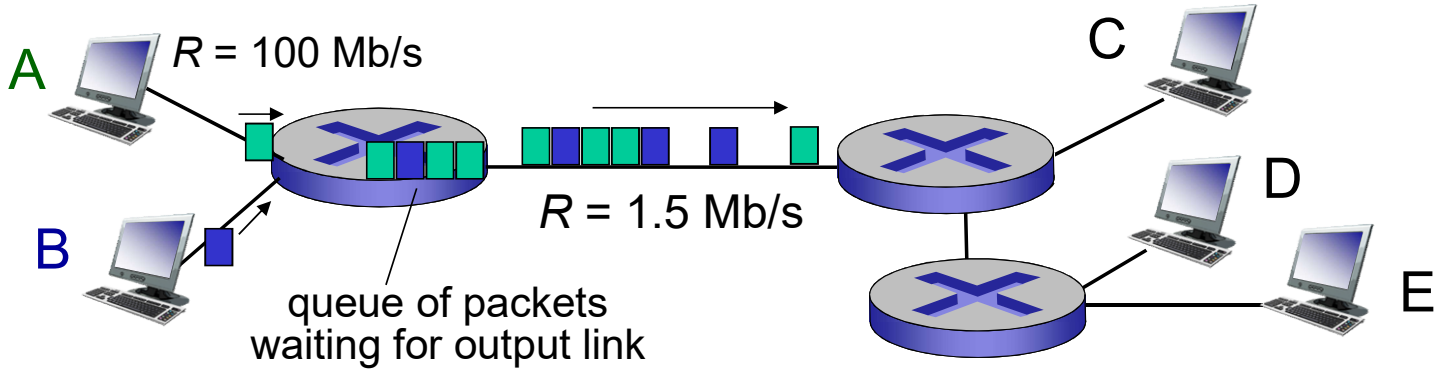
Figure 1.3 Packet Switching: Datagram Approach

Packet Switching: store-and-forward



- L-비트 패킷을 R bps 링크로 전송하면 L/R 초의 지연 발생
- store and forward:
  - ✓전체 패킷은 다음 링크로 전송되기 전에 라우터에 도착해야 한다
- 그림에서 종단간 전송지연 = 2 x L/R (전파 지연이 없다면)
  - ✓Example: L = 7.5 Mbits, R = 1.5 Mbps, e2e delay = ?

Packet Switching: queueing and loss

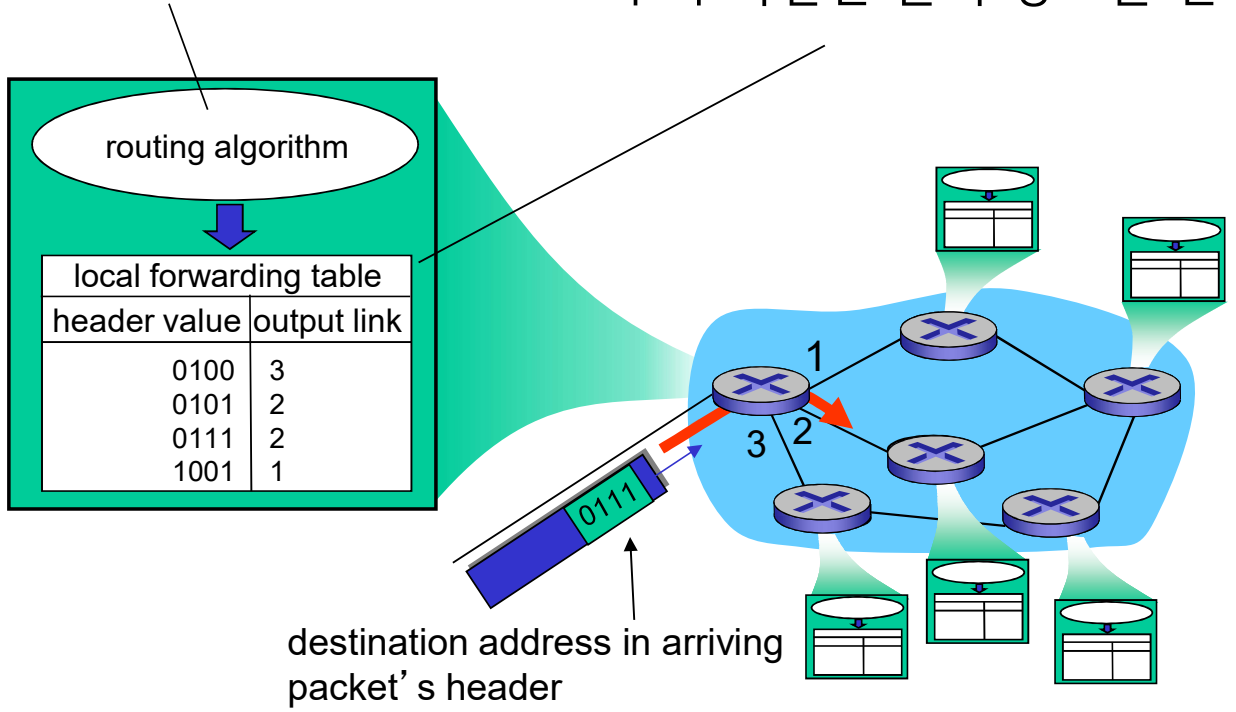


- 큐잉과 손실 (queuing and loss):
  - ✓만약, 일정 시간 동안 링크의 패킷 도착률이 패킷 전송률을 초과한다면,
    - ➢패킷은 큐잉되고 링크에서의 전송을 기다린다
    - ➢큐가 가득 찼다면 패킷은 드롭(drop)된다

Two key network-core functions

routing: 패킷 전송 경로 결정
- *routing algorithms*

forwarding: 라우터의 입력으로부터 적절한 출력 링크를 연결



Network Layer Functions

Recall: two network-layer functions:

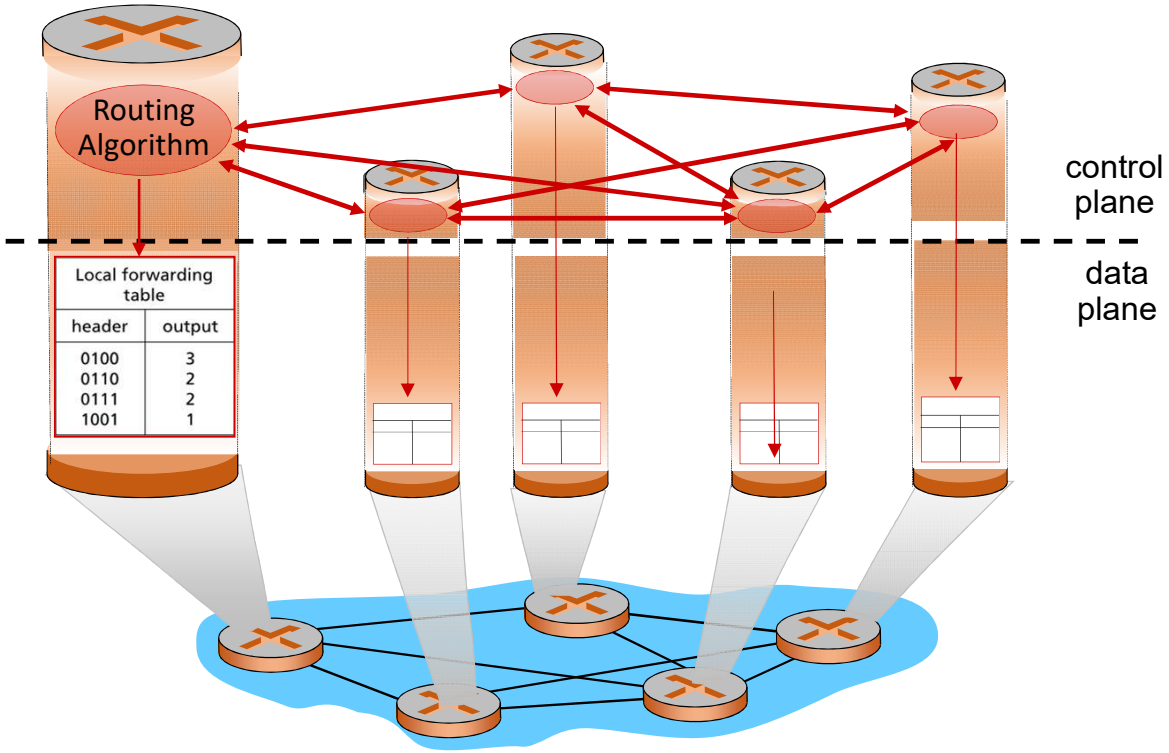
- *forwarding:* move packets from router's input to appropriate router output — *data plane*
- *routing:* determine route taken by packets from source to destination — *control plane*

Two approaches to structuring network control plane:

- per-router control (traditional)
- logically centralized control (software defined networking)

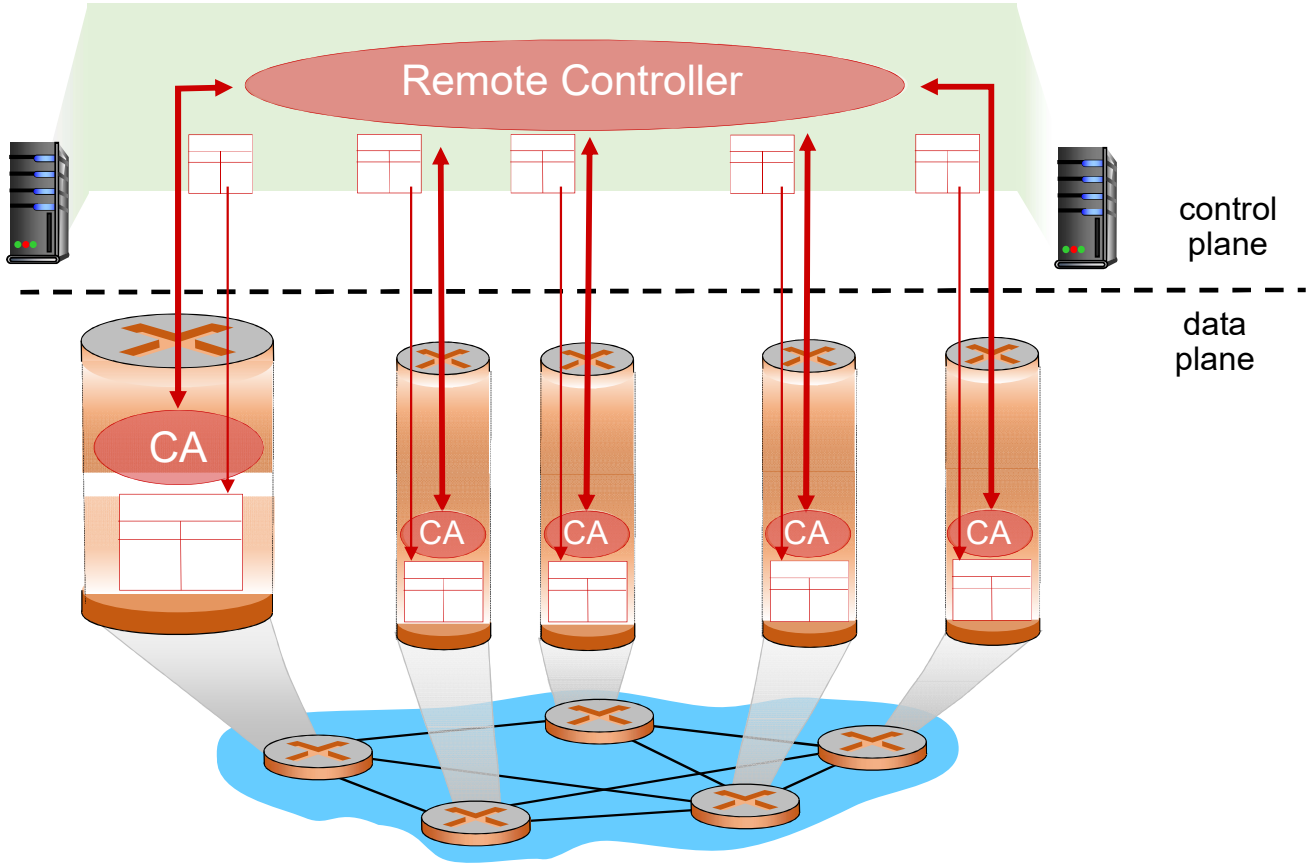
Per-Router Control Plane

- Individual routing algorithm components *in each and every router* interact with each other in control plane to compute forwarding tables



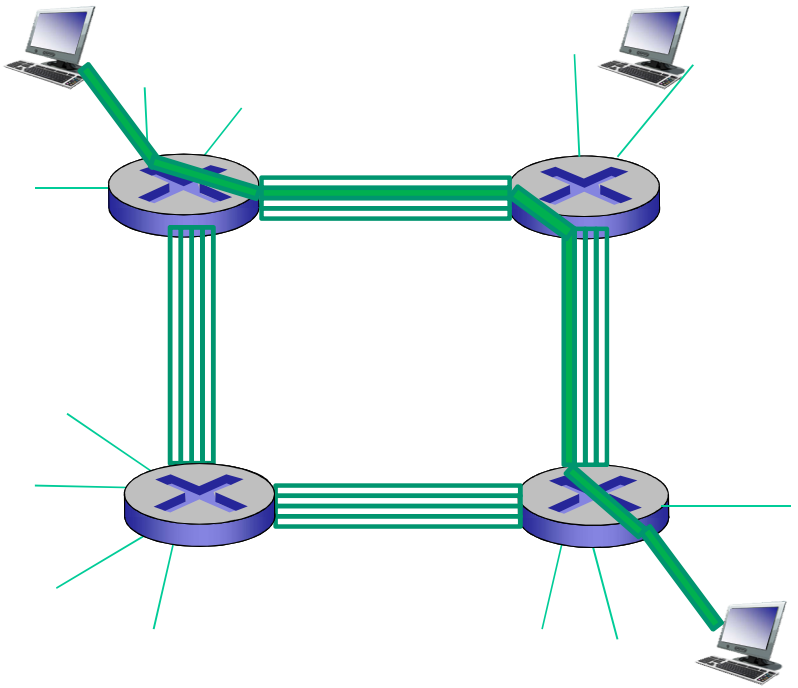
Logically Centralized Control Plane

- A distinct (typically remote) controller interacts with local control agents (CAs) in routers to compute forwarding tables



Circuit Switching

end-end resources allocated to, reserved for "call" between source & dest:



- 예),각 링크는 4개의 서킷을 가짐
- 전용 링크 사용: no sharing
  - ✓보장된 성능 발휘
- 사용하지 않는 경우 서킷은 비워진다 *(no sharing)*
- 일반적으로 전화망에서 사용

Packet Switching vs. Circuit Switching

패킷 스위칭 (Packet switching)

- bursty data를 위한 우수한 방안
  - 자원 공유 (resource sharing)
  - 단순, 셋업 과정이 없다 (simpler, no call setup)
- excessive congestion possible: packet delay and loss
  - 신뢰성 있는 데이터 전송과 혼잡 제어를 위한 프로토콜 필요

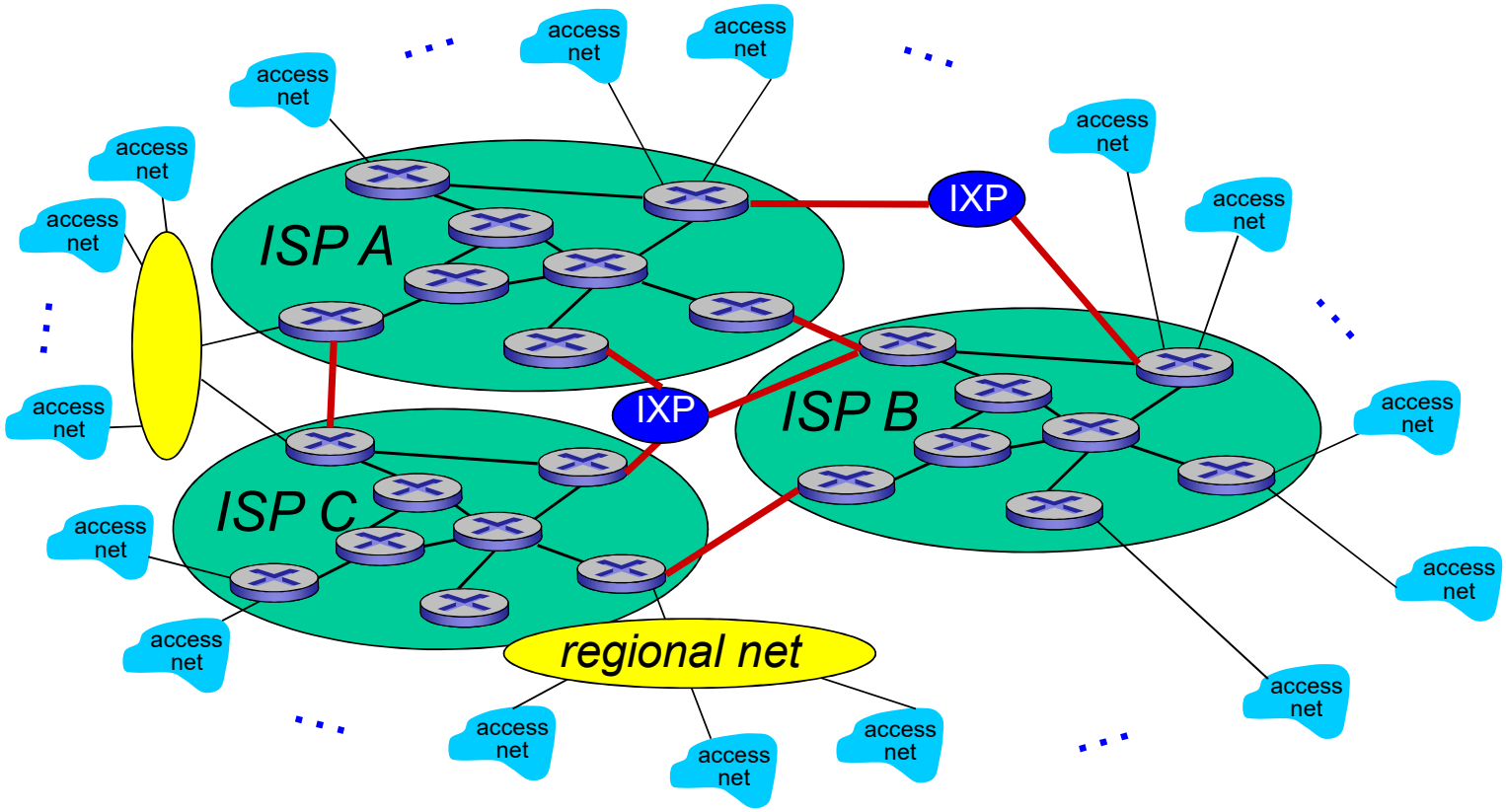
- *Q:* How to provide circuit-like behavior?
  - 멀티미디어 응용에서 요구되는 대역폭 보장 방안

Q: reserved resources (circuit switching) vs. on-demand allocation (packet switching)?

Internet structure: a network of networks

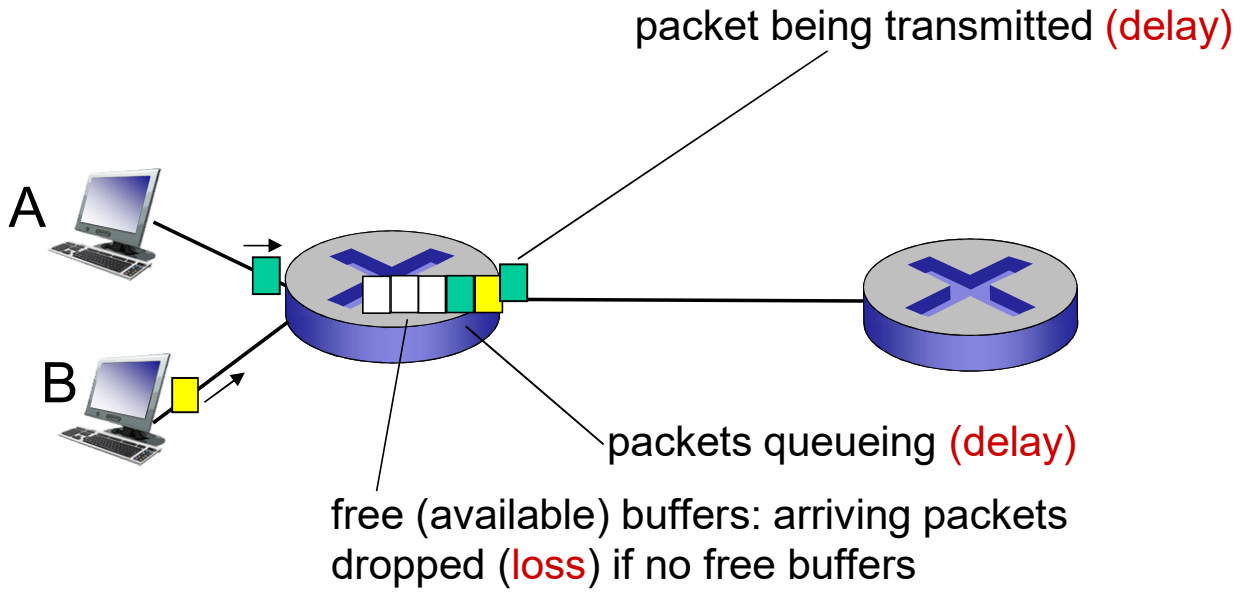
- End systems connect to Internet via access ISPs (Internet Service Providers)
  - ✓ residential, company and university ISPs
- Access ISPs in turn must be interconnected
  - ✓ so that, any two hosts can send packets to each other
- Resulting network of networks is very complex
  - ✓ evolution was driven by economics and national policies

Internet structure

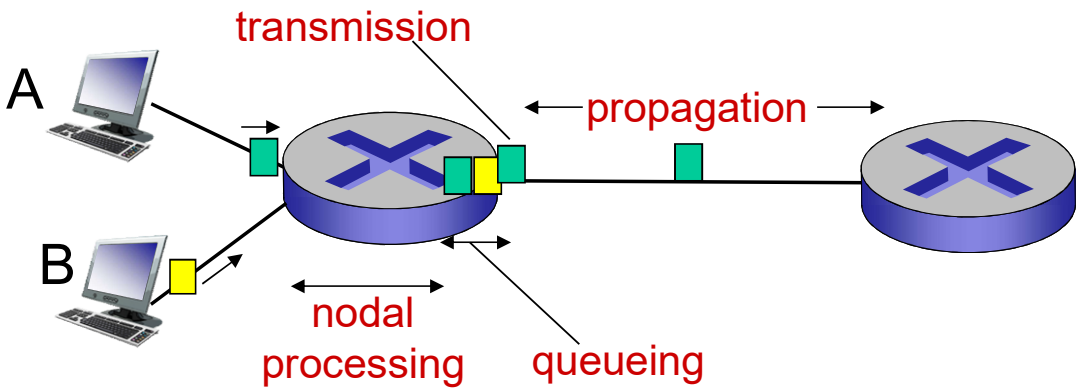


Performance – loss and delay

- 라우터 버퍼에 패킷 저장 (queueing)
  - ✓ packet arrival rate to link (temporarily) exceeds output link capacity
  - ✓ packets queue, wait for turn



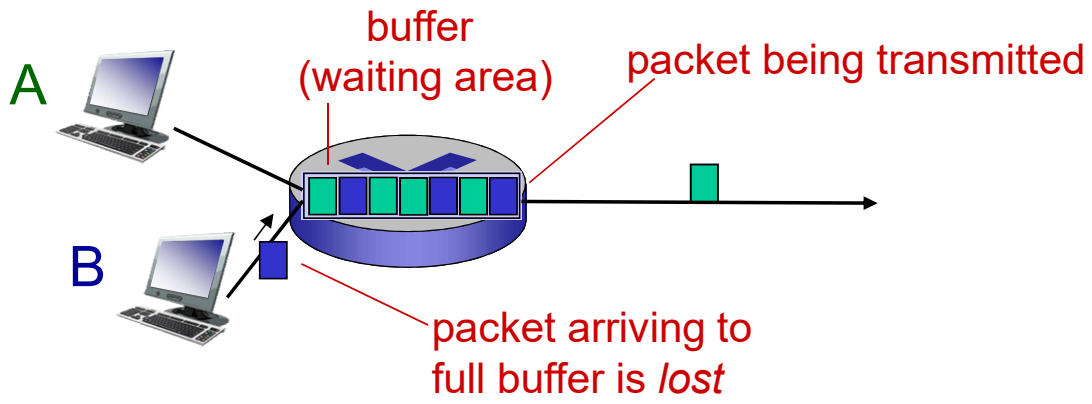
Packet Delay



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

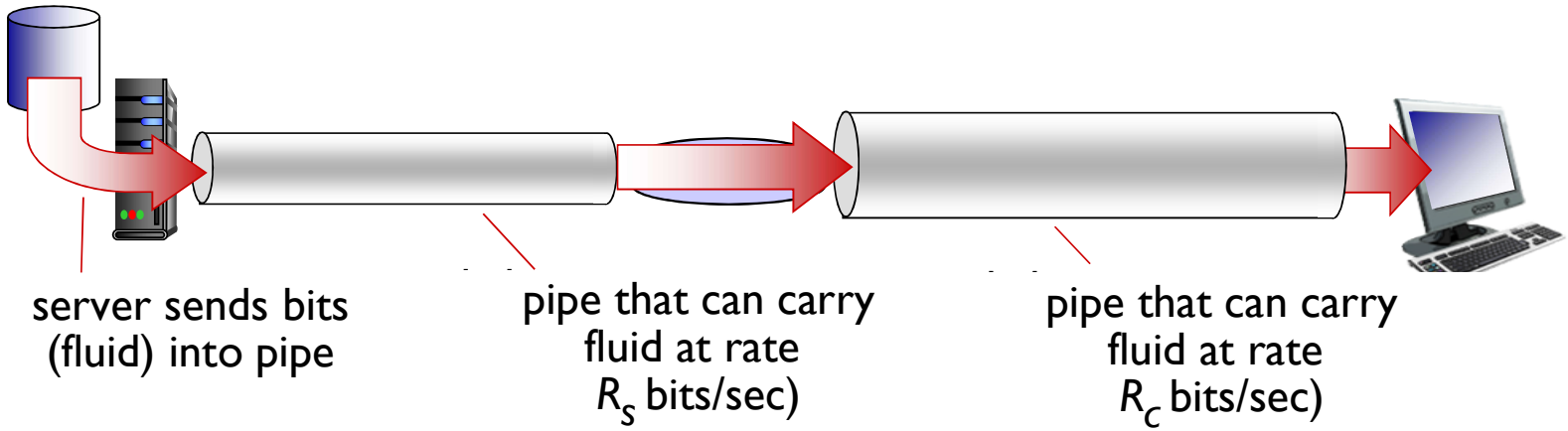
Packet Loss

- 큐는 유한한 크기를 가짐
  - ✓queue (aka buffer) preceding link in buffer has finite capacity
- 큐가 가득차면 패킷 손실 발생
  - ✓packet arriving to full queue dropped (aka lost)
- 손실된 패킷은 재전송
  - ✓lost packet may be retransmitted by previous node, by source end system, or not at all



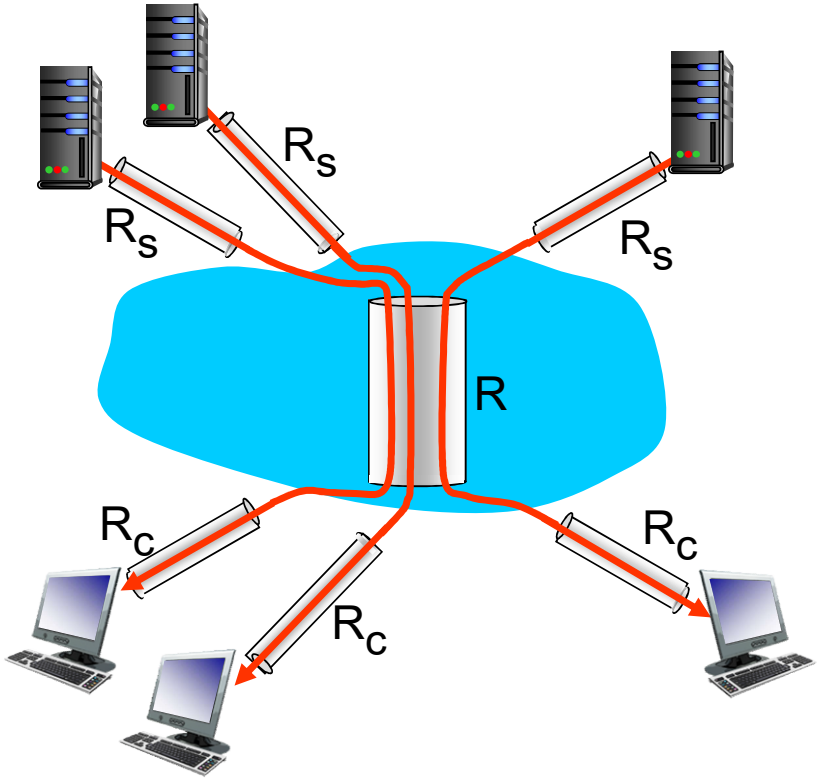
Throughput

- 처리율 (throughput): rate (bits/time unit) at which bits transferred between sender/receiver
  - ✓instantaneous (즉각적인): 특정 시점에 대한 전송률
  - ✓average (평균): 구간에 대한 전송률



Throughput: Internet scenario

- per-connection end-end throughput: *min(R_c,R_s,R/10)*



10 connections (fairly) share backbone bottleneck link *R* bits/sec

Protocol Layers

Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

Question:

is there any hope of *organizing* structure of network?

…. or at least our discussion of networks?

Why layering?

dealing with complex systems:

- 복잡한 시스템 단위에 대한 관계에 대한 명확한 구조
  - ✓layered *reference model* for discussion

- 구조화(modulation): 시스템의 유지보수 및 업데이트 용이
  - ✓레이어 구현의 변화가 기존 시스템에 영향을 주지 않는다
  - ✓e.g., change in gate procedure doesn't affect rest of system

- layering considered harmful?

OSI

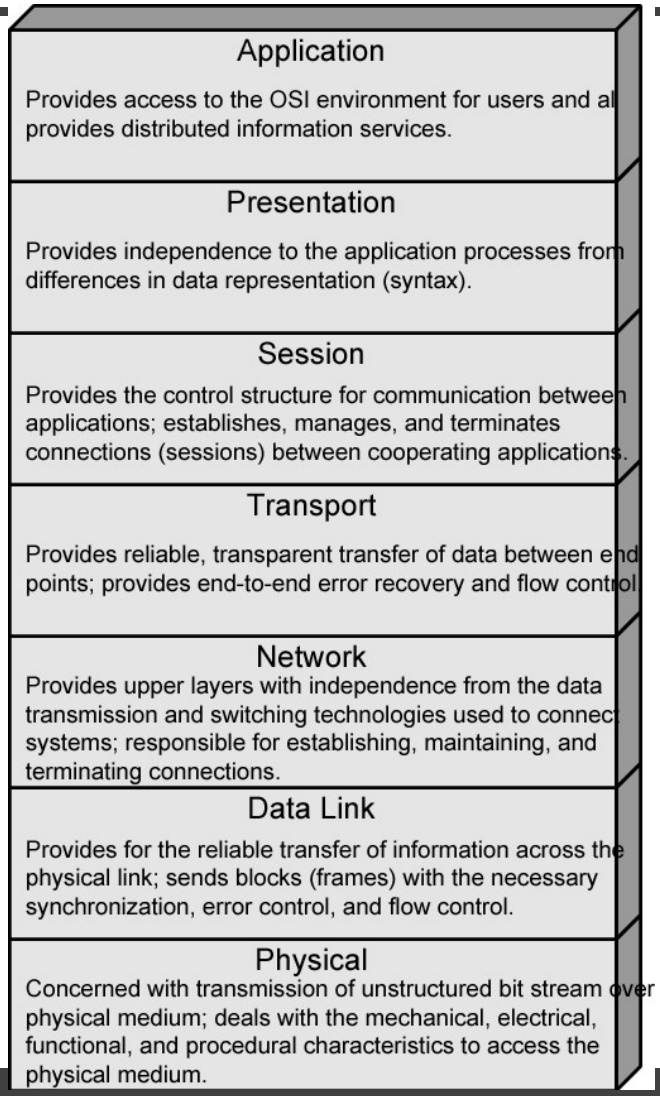
- 개방형시스템상호연결 : Open System Interconnection

- OSI 모델의 목적
  - ✓ 모든 종류의 컴퓨터 시스템 간 통신을 허용하는 네트워크 시스템 설계를 위한 계층 구조
  - ✓ 하드웨어나 소프트웨어의 변경없이 서로 다른 시스템 간 통신이 가능하도록 함
  - ✓ To open communication between different systems without requiring changes to the logic of the underlying hardware and software

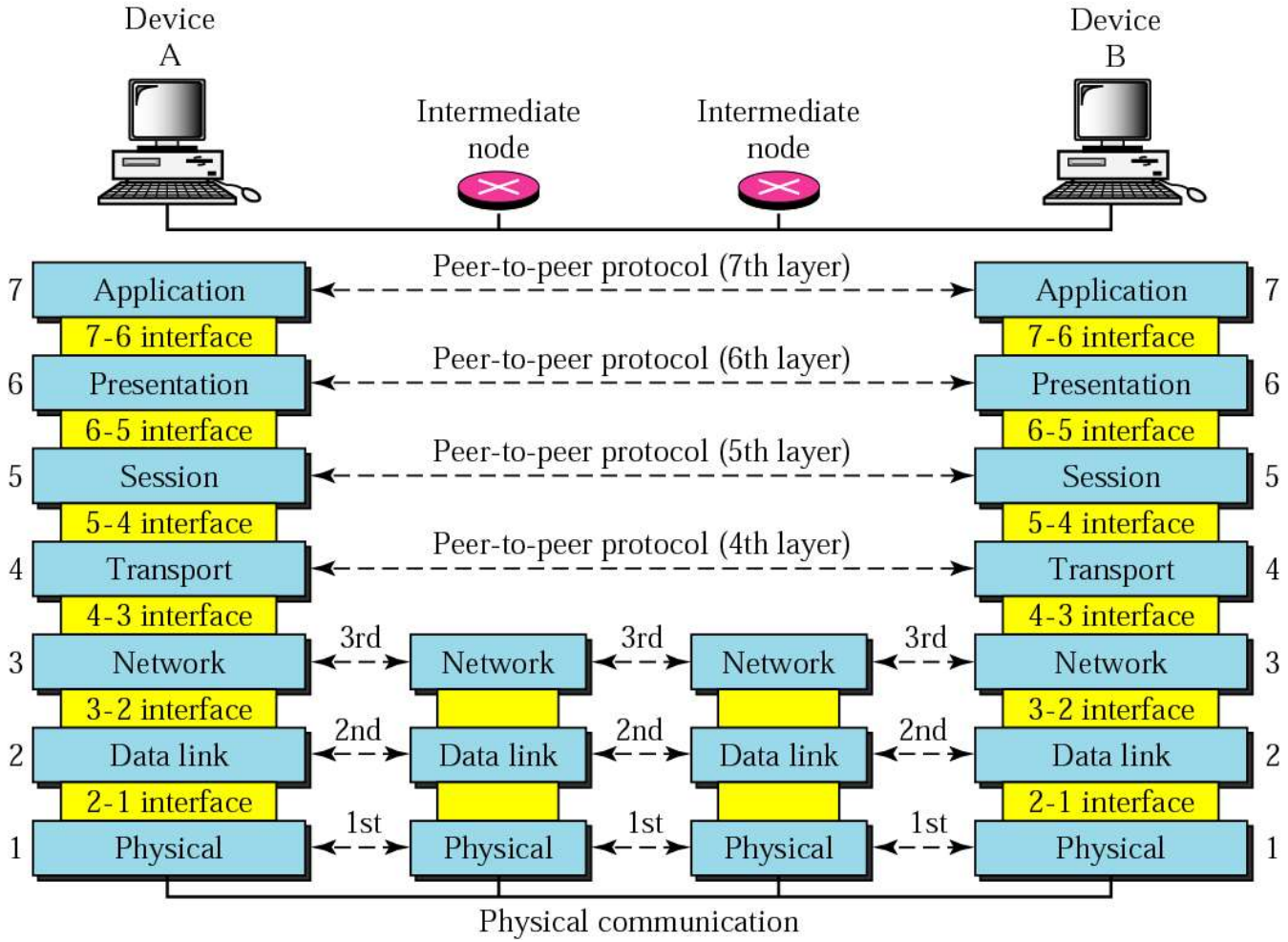
- OSI 모델
  - ✓ 네트워크 시스템 설계를 위해 계층 구조의 프레임워크를 사용한다
  - ✓ Layered framework for the design of network systems that allows for communication across all types of computer systems

OSI 7 Layers

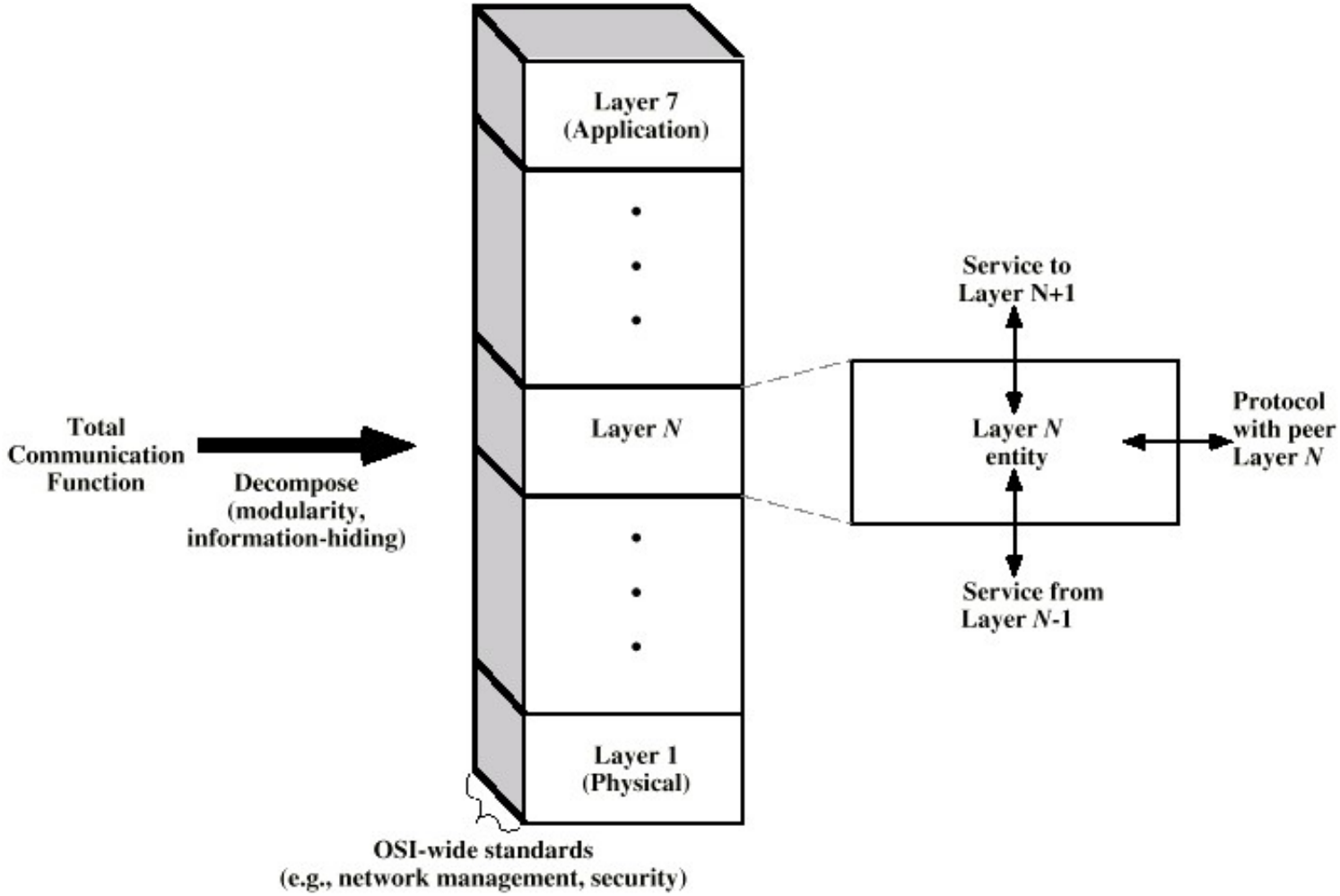
- 응용 계층
  - ✓정보 서비스 제공
- 표현 계층
  - ✓부호화, 암호화, 압축
- 세션 계층
  - ✓데이터 메시지의 동기화
- 전송 계층
  - ✓전체 메시지의 종단 대 종단 전달
- 네트워크 계층
  - ✓링크를 통해 목적지까지 패킷 전달
- 데이터 링크 계층
  - ✓노드 대 노드 전달
- 물리 계층
  - ✓비트 흐름을 전송하기 위한 기능



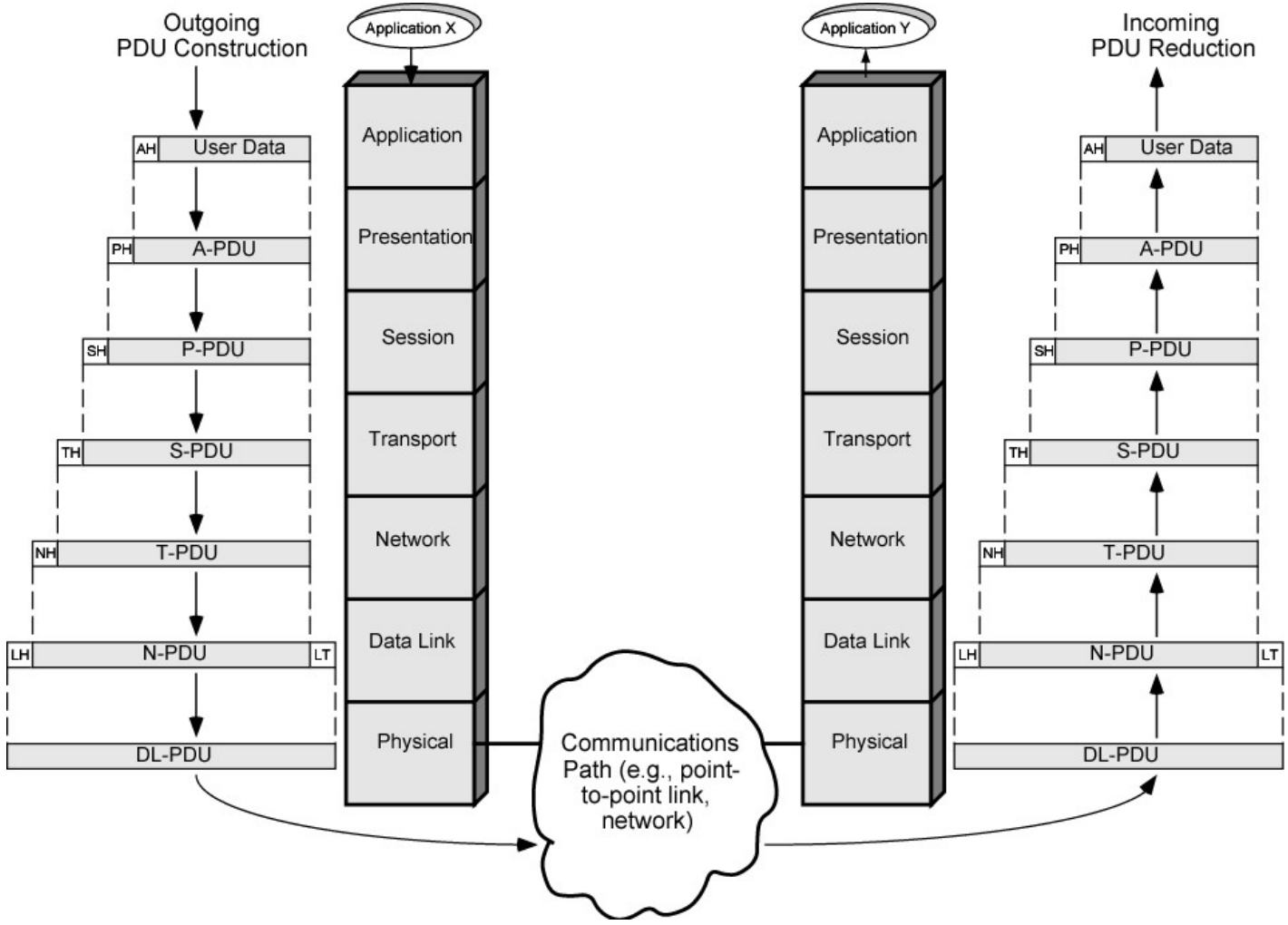
OSI 7 Layers


Device A
Intermediate node
Intermediate node
Device B
Peer-to-peer protocol (7th layer)
Peer-to-peer protocol (6th layer)
Peer-to-peer protocol (5th layer)
Peer-to-peer protocol (4th layer)
7
Application
7-6 interface
6
Presentation
6-5 interface
5
Session
5-4 interface
4
Transport
4-3 interface
3
Network
3-2 interface
2
Data link
2-1 interface
1
Physical
3rd
2nd
1st
Physical communication

OSI 7 Layers – OSI as Framework



OSI 7 Layers

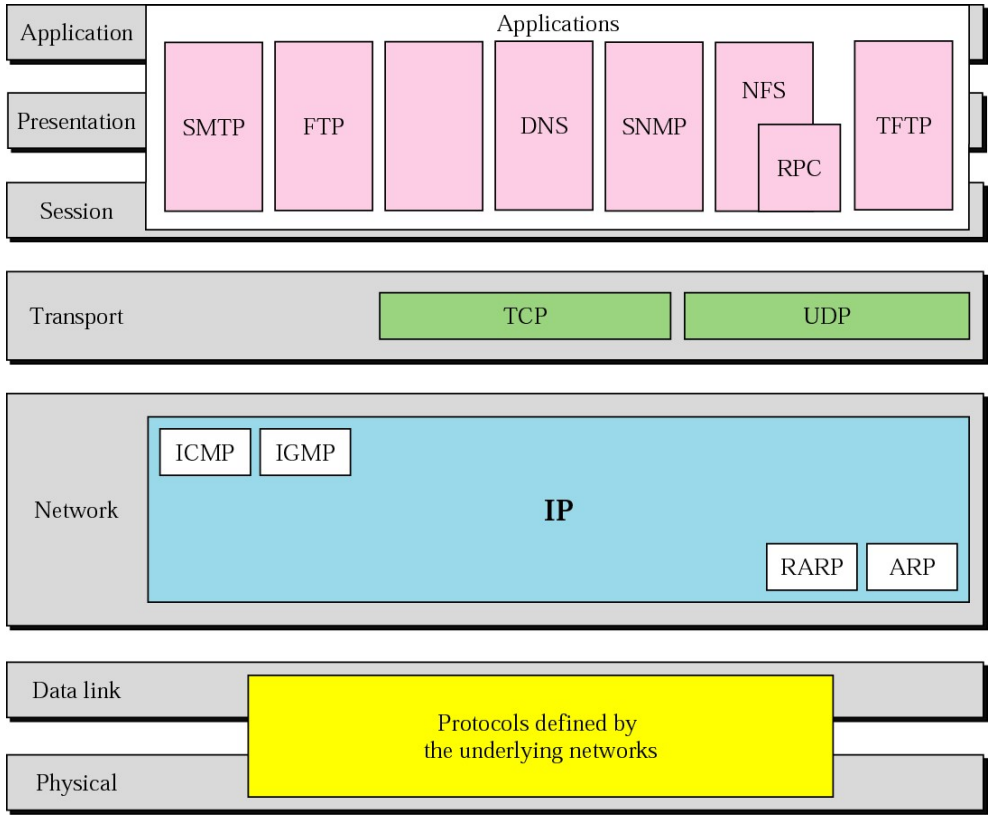

Outgoing
PDU Construction
Application X
Application Y
Incoming
PDU Reduction
AH
User Data
PH
A-PDU
SH
P-PDU
TH
S-PDU
NH
T-PDU
LH
N-PDU
LT
DL-PDU
Application
Presentation
Session
Transport
Network
Data Link
Physical
Communications
Path (e.g., point-
to-point link,
network)

OSI Reference Model

- 계층 구조 (Organization of the Layers)
  - ✓ 1, 2, 3 계층 (네트워크 지원 계층)
    - ➢ 디바이스와 디바이스간 데이터의 물리적 이동을 다룬다
    - ➢ Deal with the physical aspects of moving data from one device to another
  - ✓ 4 계층 (전송 지원 계층)
    - ➢ 하위 그룹을 연결하고 하위 계층에서 전송 한 내용이 상위 계층에서 사용할 수 있는 형식인지 확인한다
    - ➢ Links the two subgroups and ensures that what the lower layers have transmitted is in a form that the upper layers can use
  - ✓ 5, 6, 7 계층 (사용자 지원 계층)
    - ➢ 서로 다른 시스템에서 상호간 데이터 통신을 허용한다
    - ➢ Allow interoperability among unrelated software systems

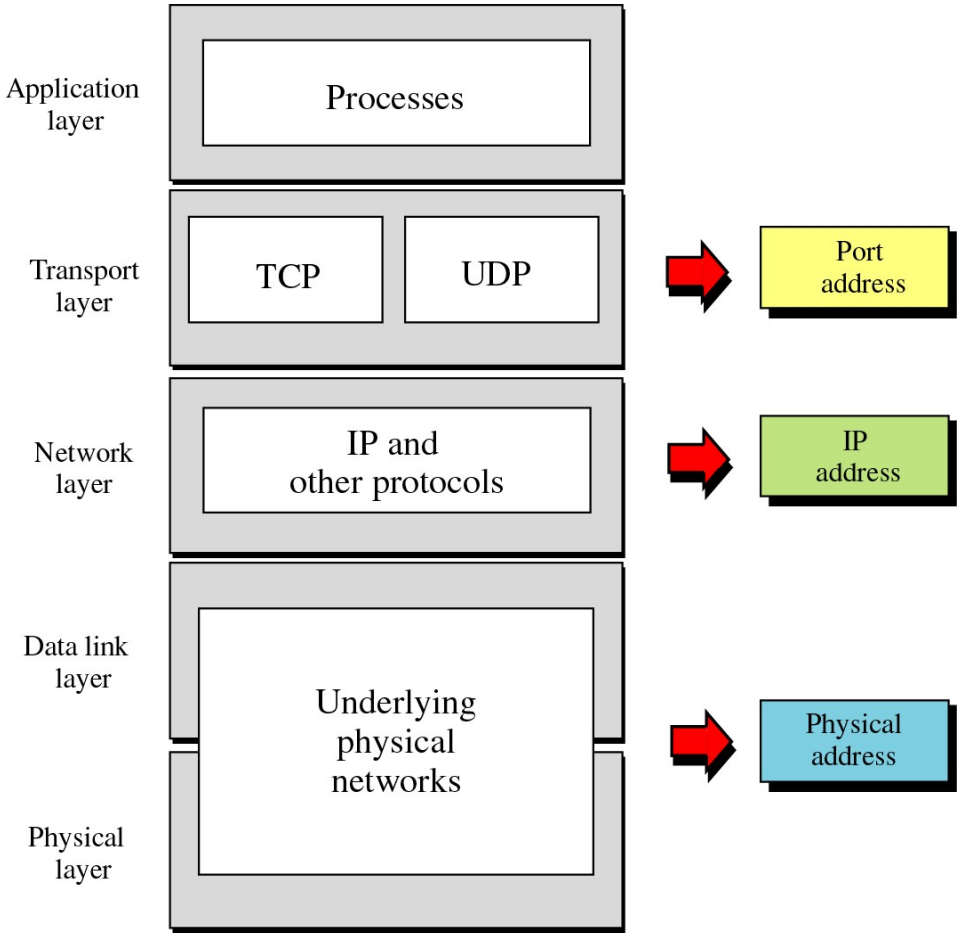
Internet Protocol Stack

- TCP/IP 프로토콜
  - ✓ OSI 모델보다 먼저 개발
  - ✓ 물리층, 데이터 링크층, 네트워크층, 전송층, 응용층 으로 구성



Addressing in TCP/IP System

- Relationship of layers and address in TCP/IP



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