링크계층3

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ARP protocol: same LAN

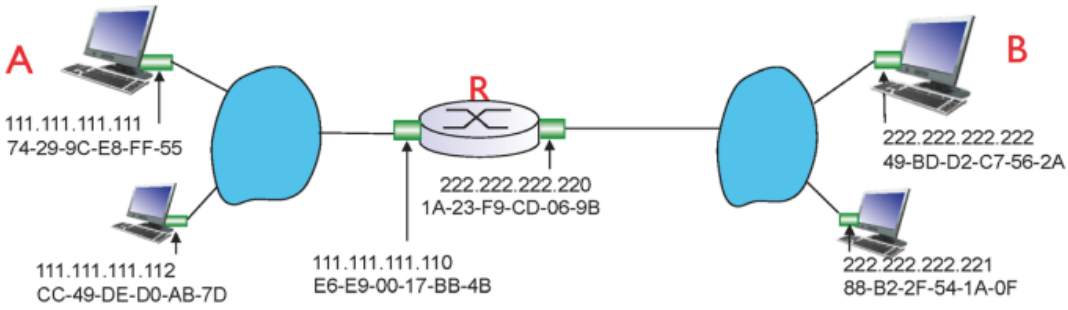
- A wants to send datagram to B
  - B's MAC address not in A's ARP table.
- A broadcasts ARP query packet, containing B's IP address
  - dest MAC address = FF-FF-FF-FF-FF-FF
  - all nodes on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's MAC address (unicast)
- A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play":
  - nodes create their ARP tables *without intervention from net administrator*

Link Layer 5-51

Addressing: routing to another LAN

walkthrough: send datagram from A to B via R

- focus on addressing – at IP (datagram) and MAC layer (frame)
- assume A knows B's IP address
- assume A knows IP address of first hop router, R (how?)
- assume A knows R's MAC address (how?)



Link Layer 5-52

GWR broadcast medium이기 때문에 충돌이 발생할 수 있는 MAC 프로토콜 즉 충돌을 어떻게 해결할 것인가

가장 유용하게 쓰이는 MAC 가 CSMA/CD 동작의 핵심

프레임을 전송하기 전에 채널을 듣고 누군가가 말하고 있으면 끝나면 전송함

collision detect가 되면 바로 멈추고 random한 시간동안 기다렸다가 재전송

충돌이 계속될 수록 random한 시간을 늘려가면서 backup

링크 단위 전송단위에 쓰이는 frame, address는 MAC adress

48bit짜리 주소 공간 IP 와 같지 않음 / 고유의 주소임

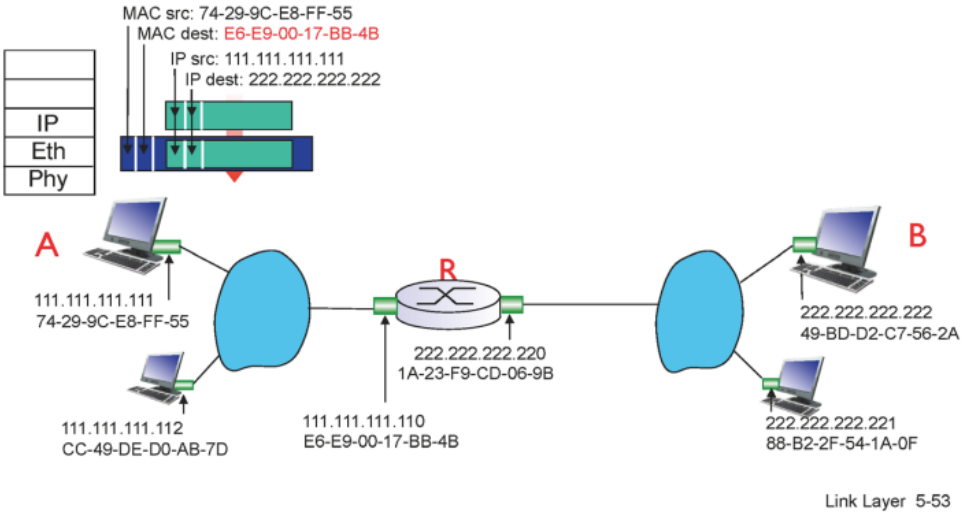
ip주소를 담은 저 링크 frame에 사용되기 때문에 우리는 ip주소를 담음 mac frame을 전송할 때 그 목적지에 해당하는 다음의 mac address를 알아내서 mac frame의 destination field에 알맞게 적어놔야 전송이 됨

그 다음 곳에 있는 MAC address를 알아내기 위해 쓰는거 ARP protocol을 사용해 해결

ARP protocol lookup을 통해 주소를 알아냄

Addressing: routing to another LAN

- A creates IP datagram with IP source A, destination B
- A creates link-layer frame with R's MAC address as dest, frame contains A-to-B IP datagram



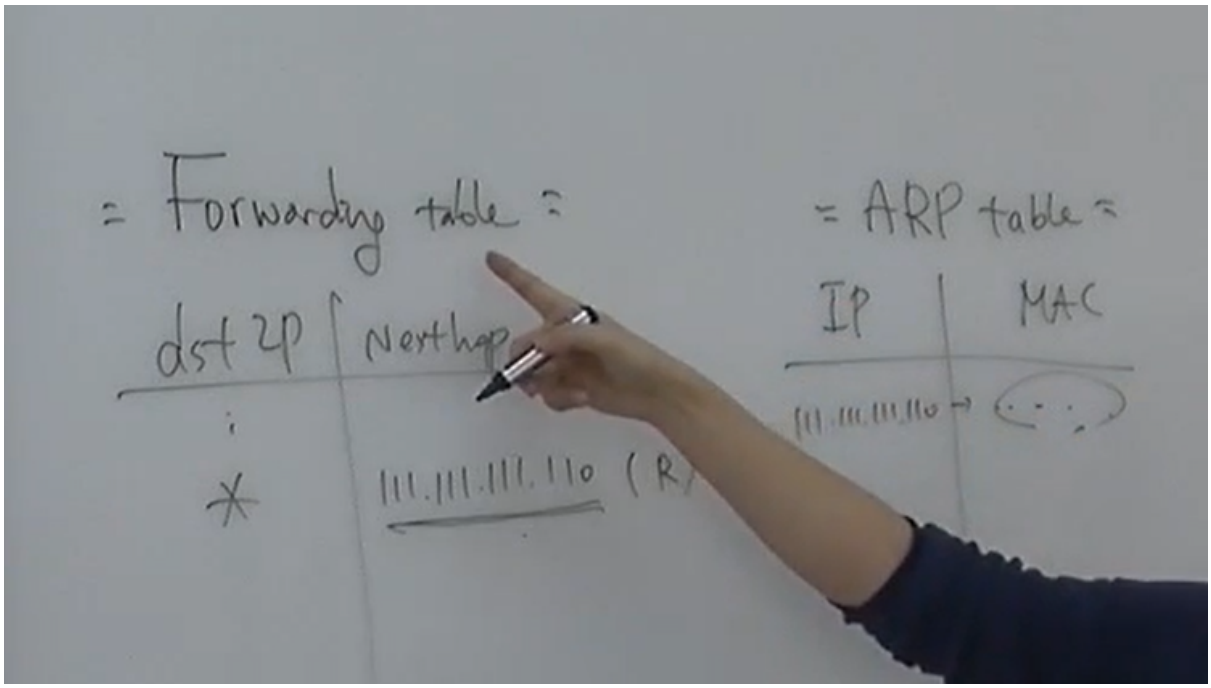
Link Layer 5-53

A가 B한테 보낼라 하는데 중간에 R이 있다 두개의 서브넷에 포함됨

왼쪽과 오른쪽의 주소가 당연히 다름

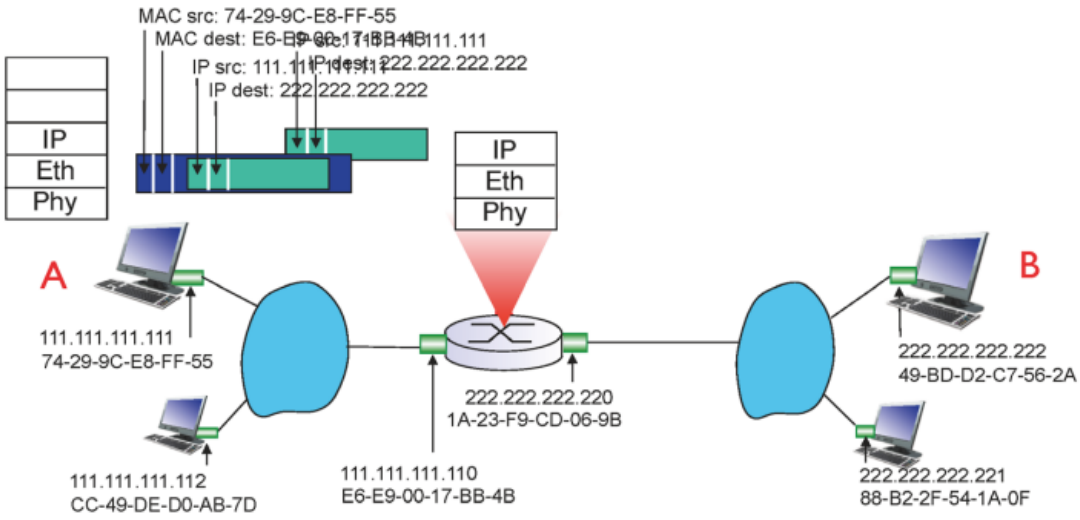
B의 ip주소는 DS를 통해 알아냄

A 내부의 Forwarding table을 보면



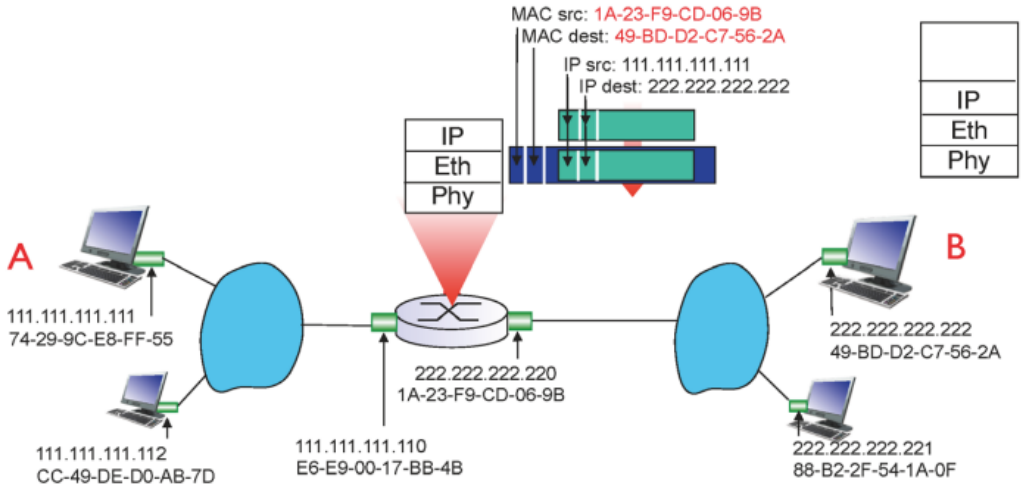
Addressing: routing to another LAN

- frame sent from A to R
- frame received at R, datagram removed, passed up to IP



Addressing: routing to another LAN

- R forwards datagram with IP source A, destination B
- R creates link-layer frame with B's MAC address as dest, frame contains A-to-B IP datagram



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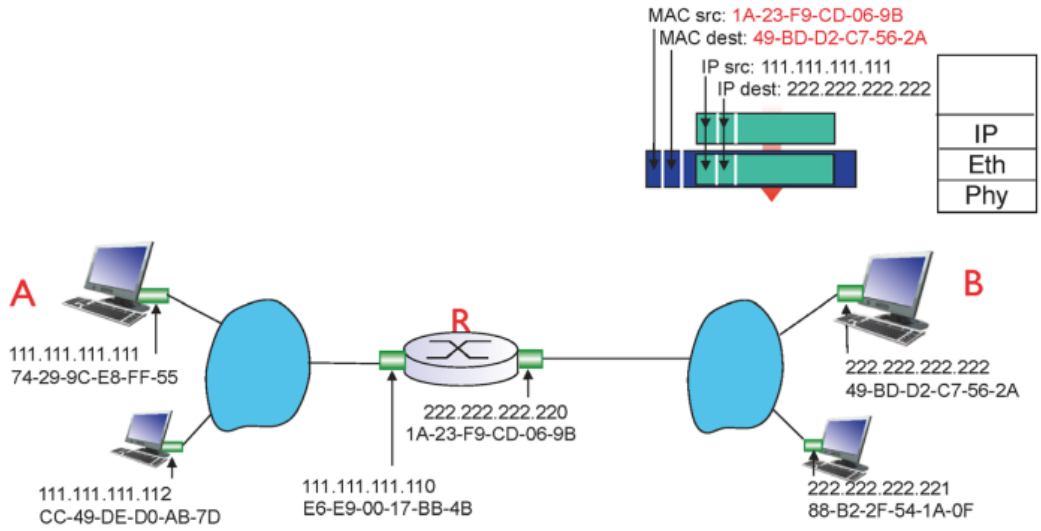


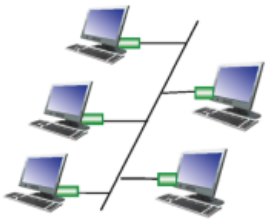
Link layer, LANs: outline

5.1 introduction, services
5.2 error detection, correction
5.3 multiple access protocols
5.4 LANs
- addressing, ARP
- Ethernet
- switches
- VLANS

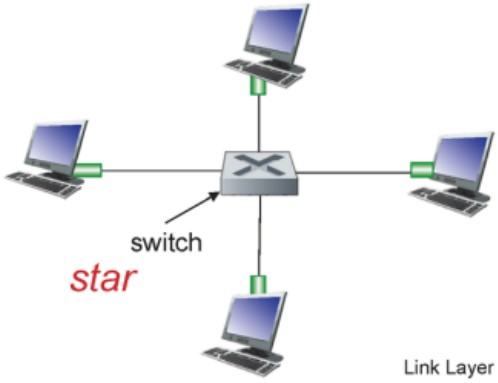
5.5 link virtualization: MPLS
5.6 data center networking
5.7 a day in the life of a web request

Ethernet: physical topology

- *bus:* popular through mid 90s
  - all nodes in same collision domain (can collide with each other)
- *star:* prevails today
  - active *switch* in center
  - each "spoke" runs a (separate) Ethernet protocol (nodes do not collide with each other)



bus: coaxial cable



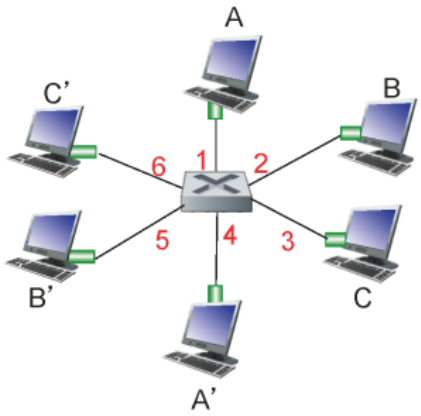
Link Layer 5-59

swirch : collision domain을 분리해줌

host들 눈에는 보이지 않음 : 없는 존재

Switch: *multiple* simultaneous transmissions

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *switching:* A-to-A' and B-to-B' can transmit simultaneously, without collisions



switch with six interfaces (1,2,3,4,5,6)

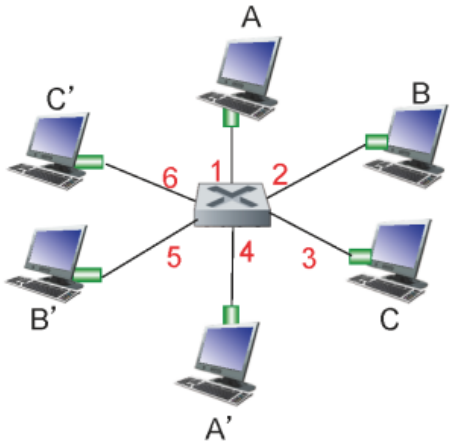
Switch forwarding table

Q: how does switch know A' reachable via interface 4, B' reachable via interface 5?

- *A: each switch has a switch table, each entry:*
  - *(MAC address of host, interface to reach host, time stamp)*
  - *looks like a routing table!*

Q: how are entries created, maintained in switch table?

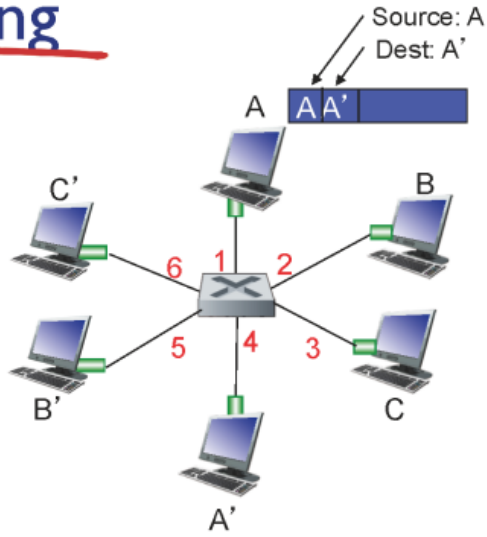
- *something like a routing protocol?*



switch with six interfaces (1,2,3,4,5,6)

Switch: self-learning

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table



MAC addr	interface	TTL
A	*1*	*60*

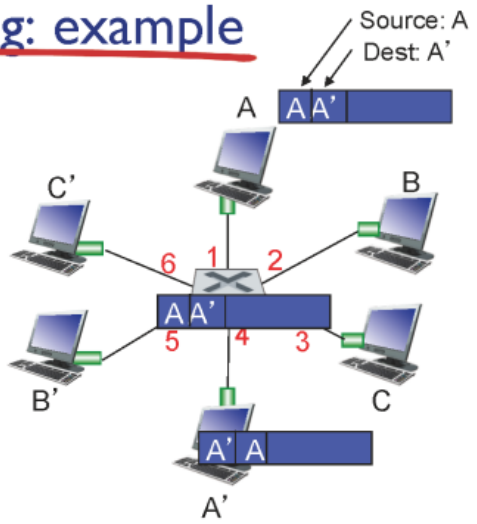
Switch table (initially empty)

Link Layer 5-63

A는 단순히 frame을 만들어서 A'한테 보내려구 하는것

Self-learning, forwarding: example

- frame destination, A', locaton unknown: *flood*
- destination A location known: *selectively send on just one link*

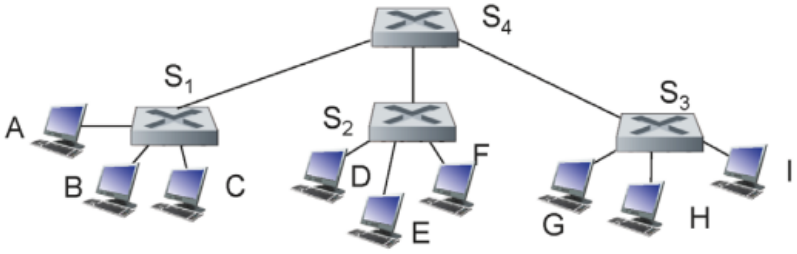


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting switches

- switches can be connected together

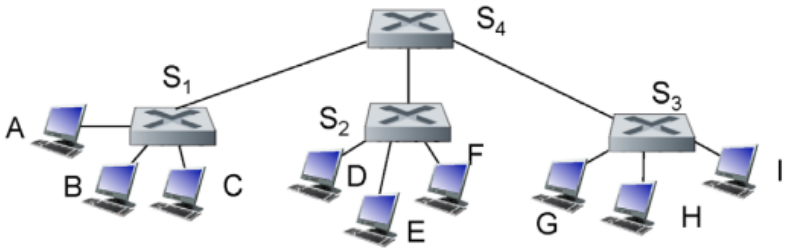


Q: sending from A to F - how does S_1 know to forward frame destined to F via S_4 and S_3?

- A: self learning! (works *exactly* the same as in single-switch case!)

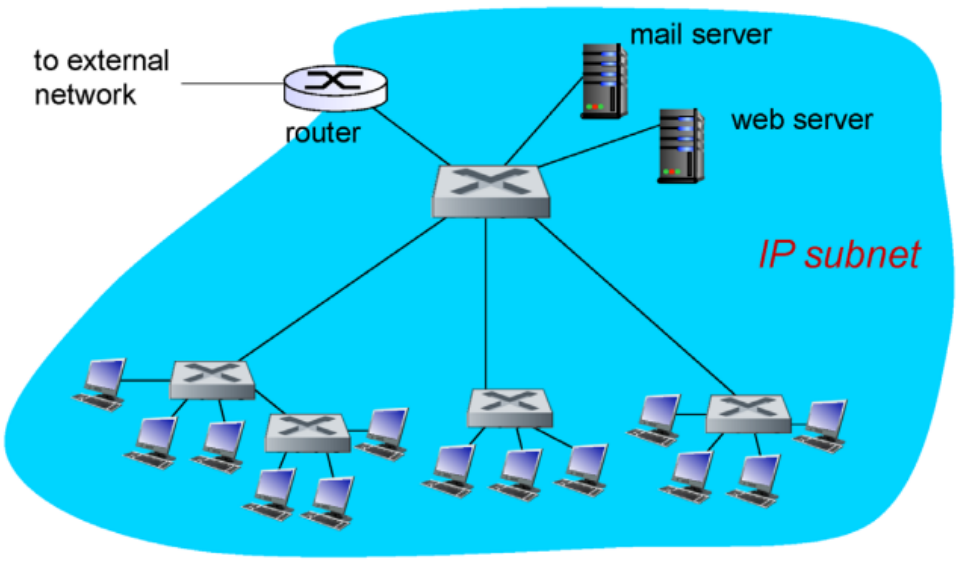
Self-learning multi-switch example

Suppose C sends frame to I, I responds to C



- *Q:* show switch tables and packet forwarding in S_1, S_2, S_3, S_4

Institutional network



switch들로 연결되어있다 GateWayRouter가 있긴 있지만 직접적으로 연결된 게 아니라 switch들로 연결되어있다.

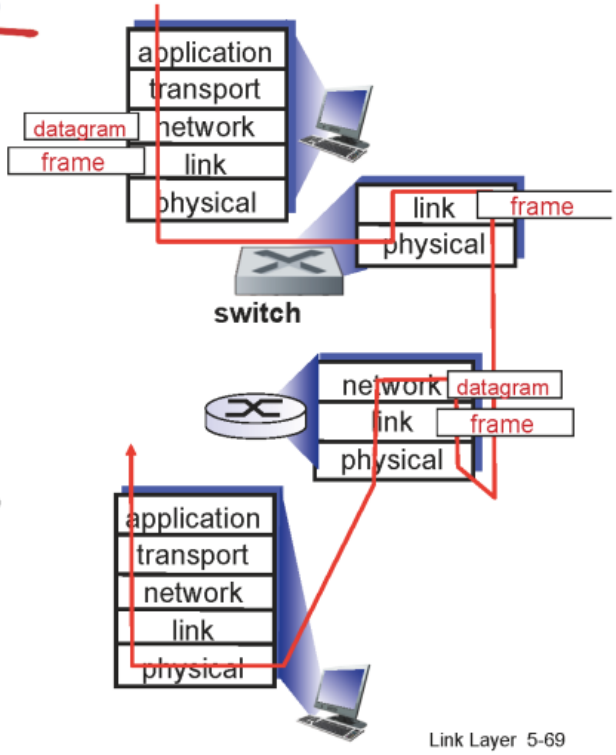
Switches vs. routers

both are store-and-forward:

- *routers:* network-layer devices (examine network-layer headers)
- *switches:* link-layer devices (examine link-layer headers)

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



Link Layer 5-69

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5.7 a day in the life of a web request

Data center networks

- 10's to 100's of thousands of hosts, often closely coupled, in close proximity:
  - e-business (e.g. Amazon)
  - content-servers (e.g., YouTube, Akamai, Apple, Microsoft)
  - search engines, data mining (e.g., Google)
- challenges:
  - multiple applications, each serving massive numbers of clients
  - managing/balancing load, avoiding processing, networking, data bottlenecks

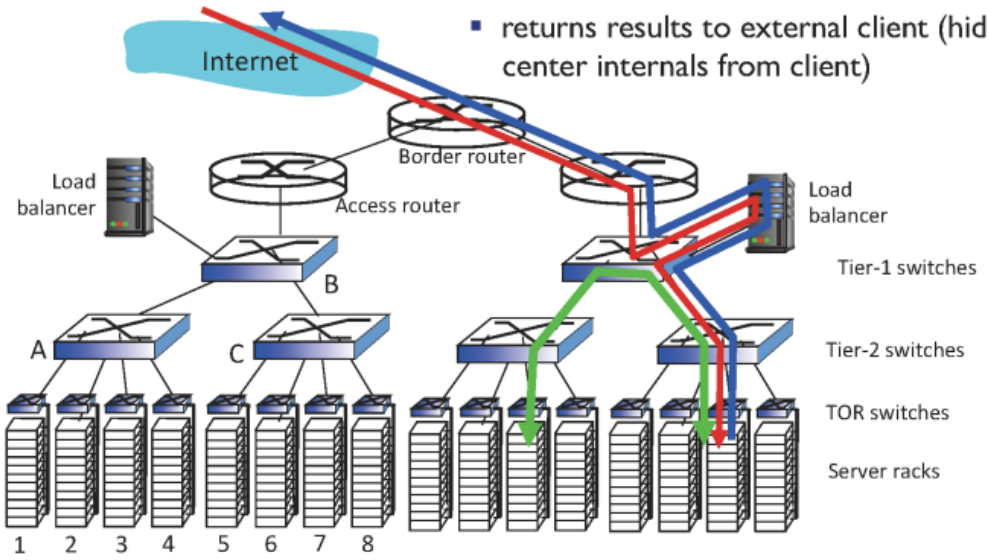
Inside a 40-ft Microsoft container, Chicago data center

스위치의 계층화

Data center networks

load balancer: application-layer routing

- receives external client requests
- directs workload within data center
- returns results to external client (hiding data center internals from client)



Link Layer 5-84

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A day in the life: scenario