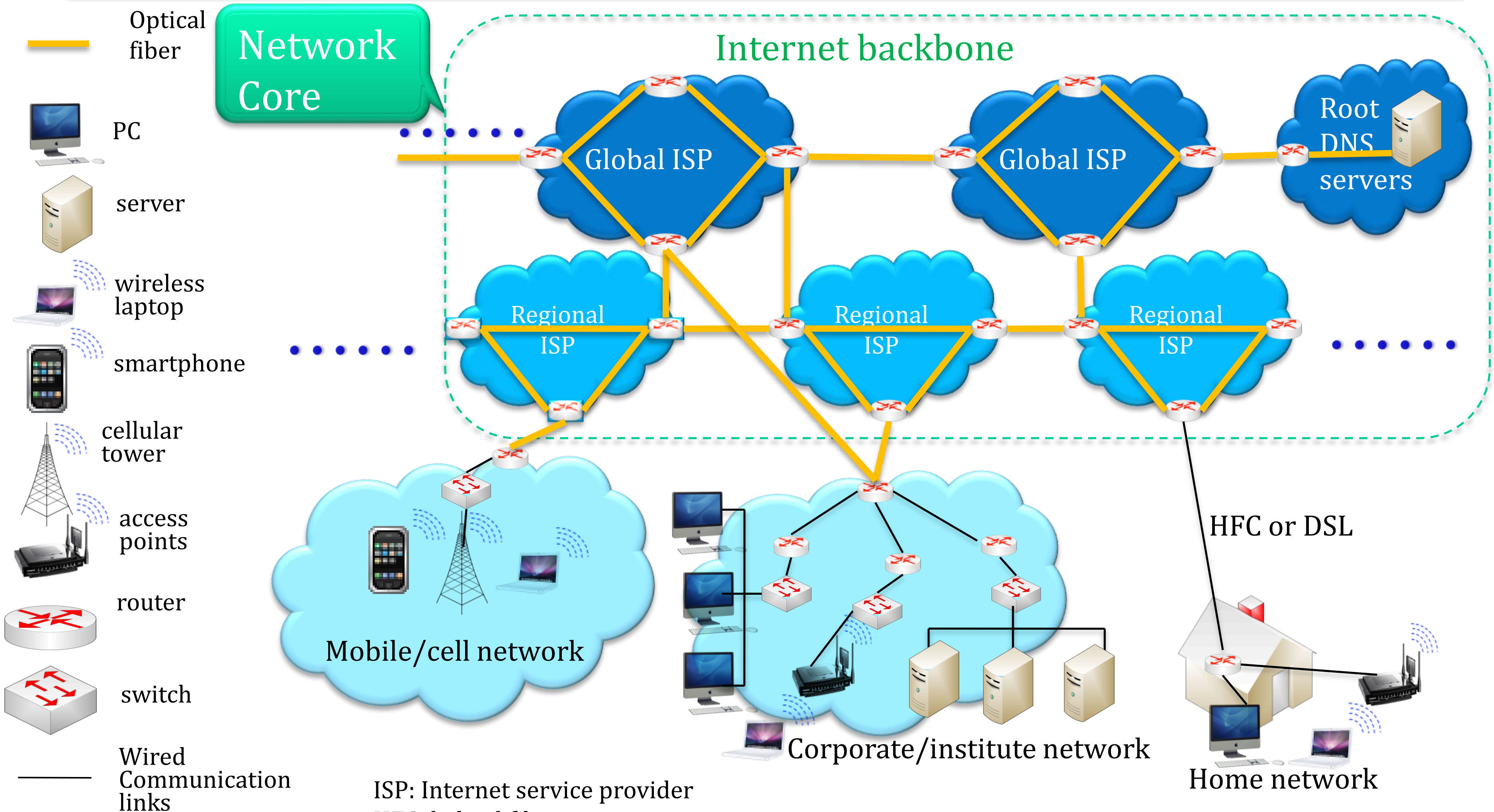
Chapter 0 Outline

Part 0

- ❀ Internet architecture
- ❀ Access networks
- ❀ Network core
- ❀ Packet switching and circuit switching
- ❀ Packet Switching Delays
- ❀ Protocol stack
- ❀ Internet history

Internet architecture (1)



ISP: Internet service provider
HFC: hybrid fiber coax
DSL: digital subscriber line

Internet architecture (2)

- Internet
  - connects billions of hosts
  - hosts are end systems (clients/server)
  - running network applications
- Communication links
  - connects end systems/routers/switches/access points
  - fiber, copper and radio
  - transmission rate/bandwidth
  - resource allocation/reservation
- Routers
  - connects local area networks
  - Generates/maintains a routing table
  - forwards packets

Internet architecture (3)

- Access networks
  - connects a local area network or a host to the Internet
- Internet backbone (network core)
  - a group of interconnected routers using optical fiber
  - infrastructure name servers, such as DNS root servers for Naming

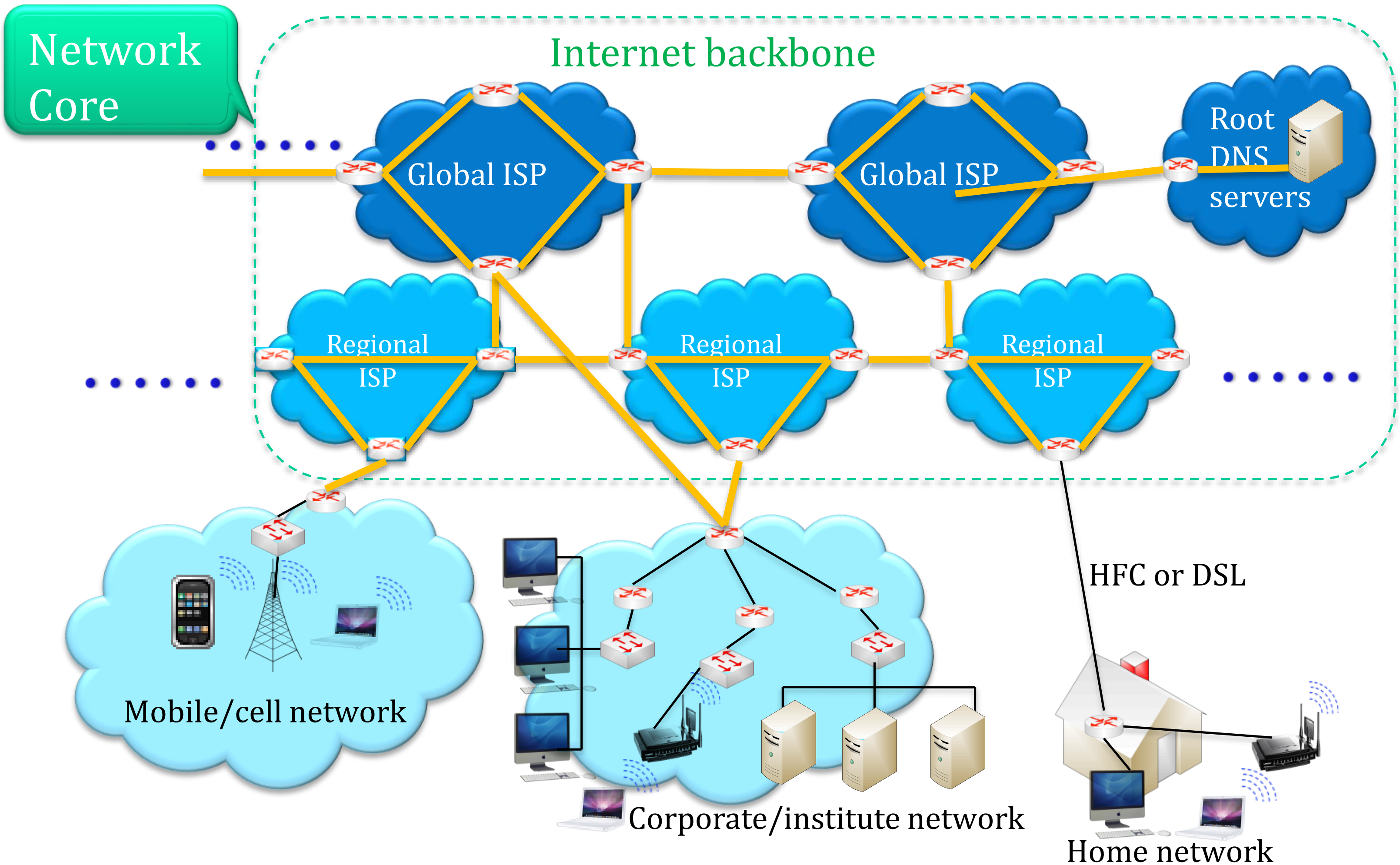
Internet architecture (4)

- Internet: an interconnected network of networks
  - Hierarchical networks:
    - Internet backbone: connecting the ISPs' backbones
    - ISP backbone: connecting organizations' backbones
    - Organization backbone connects local area networks (LANs)
    - LAN connects end systems
  - Public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force
    - Free download of RFCs at rfc-editor.org

Network Core, Access Networks and Edge

- Network edge
  - Hosts: server, client, P2P
  - Applications: http, mail, Facebook, Twitter
- Network core
  - Edge router: connecting an organization/ISP to the Internet
  - Interconnection of routers using fiber
  - Naming services
- Access networks
  - Wired, or wireless communication links

Network core and edge



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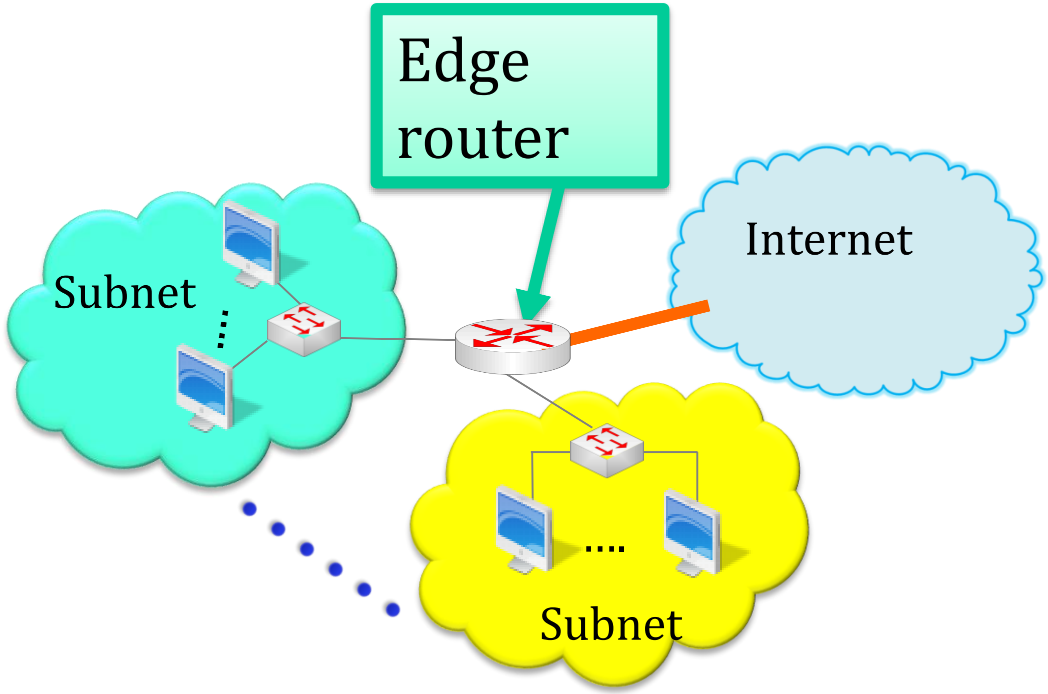
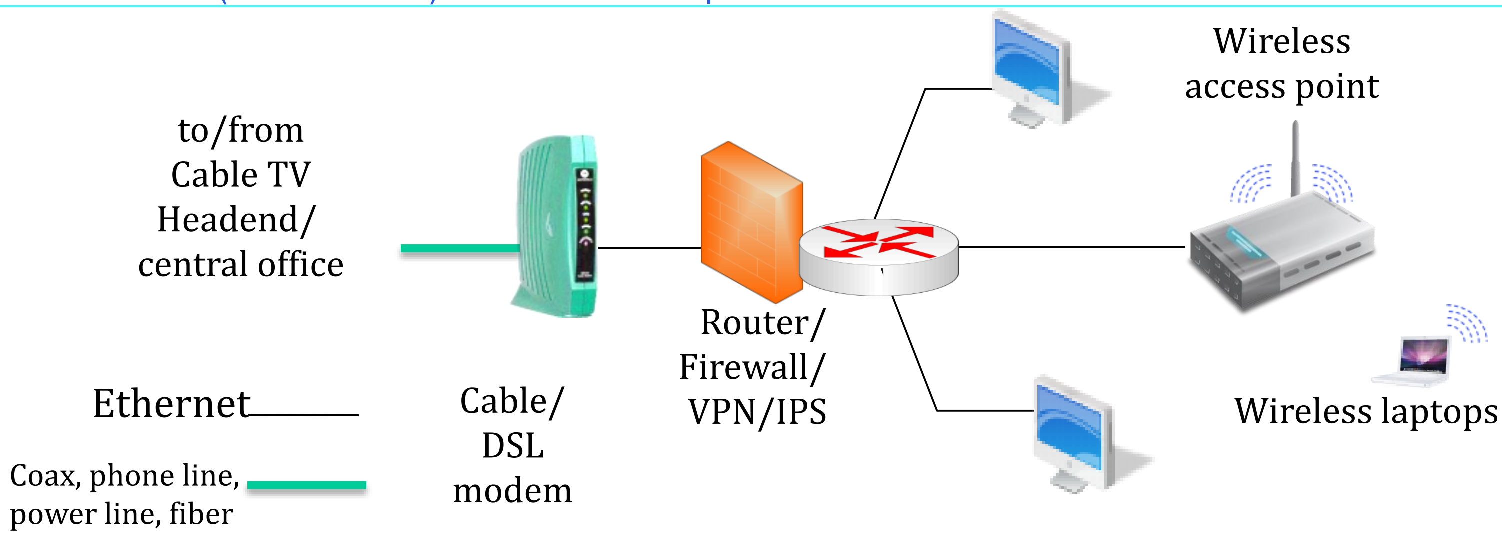
Router and subnet



❀ Internet uses a gateway (edge router) to connect a Local Area Network (LAN) or a subnet to the hierarchical network

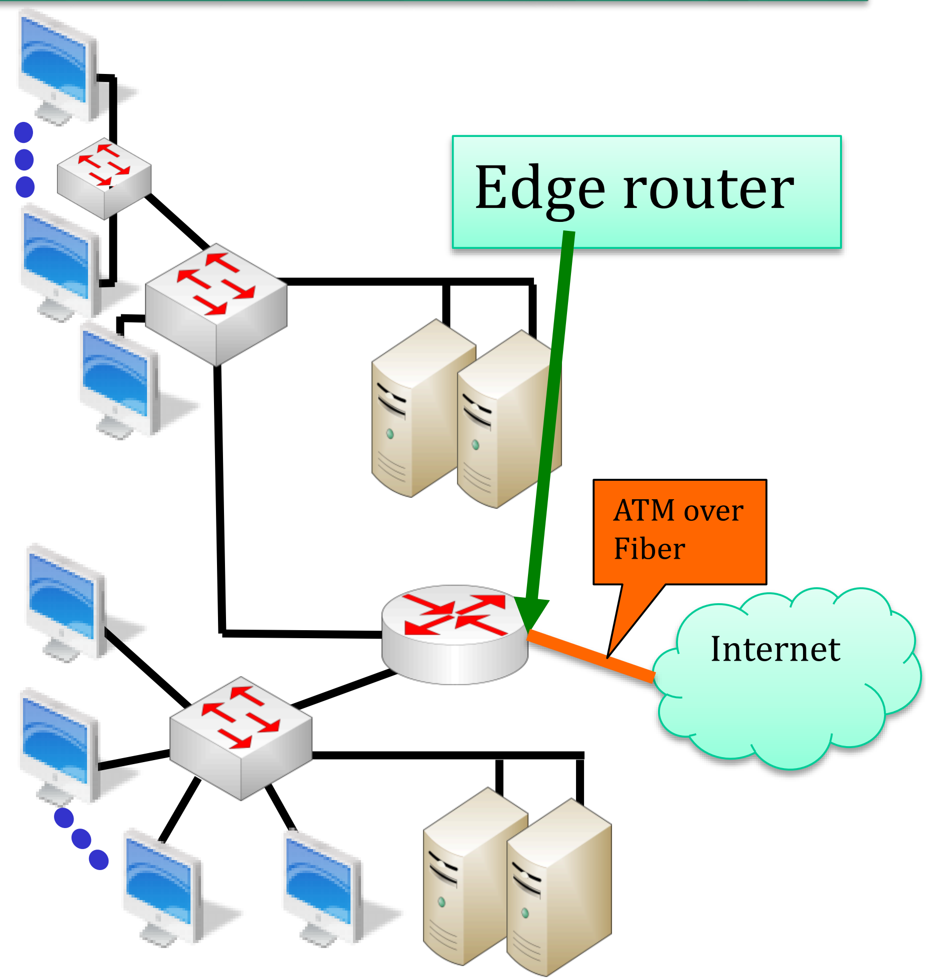
Home networks

- DSL or cable modem to ISP
- Router cannot perform routing functions such as generating routing tables
  - It is called a router because of NAT (network address translation)
  - E.g., 192.168.1.x to a given IP address from ISP
- Router that may contain a firewall/VPN/IPS
  - VPN: virtual private network
  - IPS: intrusion prevention system
- Ethernet switch (built in router)/wireless access point



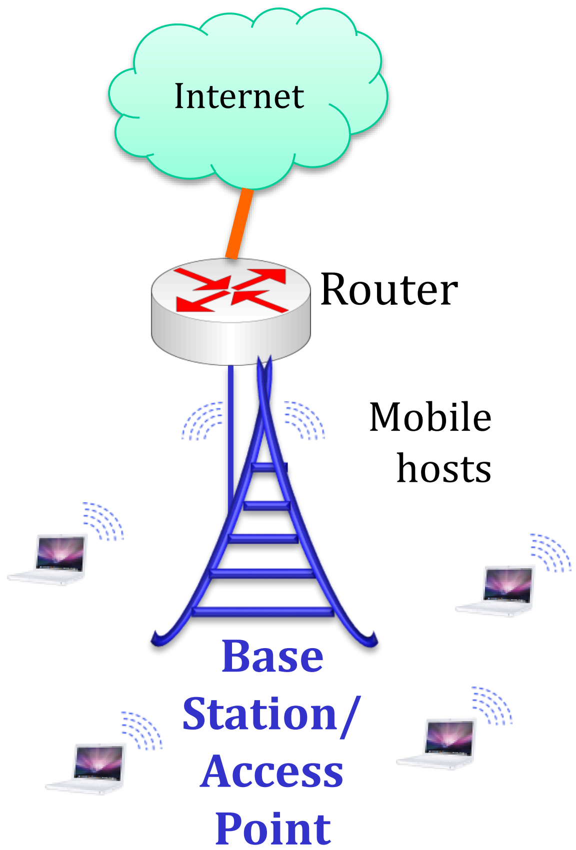
Local area network connected to Internet

- Organization/home local area network (LAN) or subnet connects hosts to edge router
- Edge router connects LANs to Internet
  - Telco uses ATM over fiber
- Ethernet LAN
  - Hosts connect into Ethernet switch
  - 10Mbps, 100Mbps, 1Gbps, 10Gbps Ethernet
- LANs: Part 3
- ATM: asynchronous transfer mode



Wireless access networks

- Shared wireless access network connects hosts to router
  - Via base station or access point
- Wireless LANs:
  - 802.11a/b/g (WiFi): 11 or 54 Mbps
  - 802.11n > 100 Mbps
  - 802.11ac > 430 Mbps
    - Chip from Broadcom: Wi-Fi with a 1.3 Gbps
    - The chips run only in the cleaner 5GHz band
    - The IEEE spec won't be ready until 2013
- Wider-area wireless access
  - Provided by telco operator
  - ~1 Mbps over cellular system (EVDO, HSDPA, LTE)
  - WiMAX (10's Mbps) over wide area



Physical Media

- Physical link: medium between transmitter & receiver
- Transmission line (wire): signals propagate in a medium
  - Twisted copper pair: Ethernet 100BASE-T, 1000BASE-T, 10GBASE-T
  - Coax: 10BASE2
  - Fiber: 100BASEF, 1000BASEX, 10GBASE-R
- Free space: signals propagate in free space, e.g., radio waves
  - Wireless LAN: 802.11
  - 3G wireless: HSDPA, EV-DO
  - LTE, WiMAX
  - Satellite

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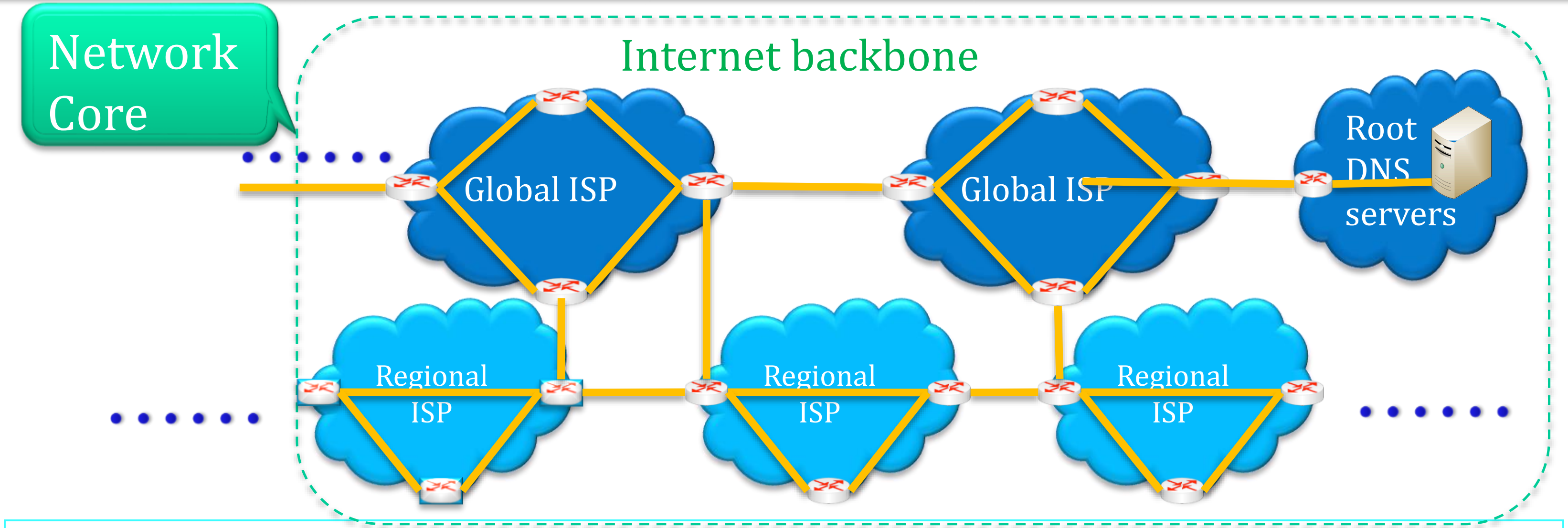
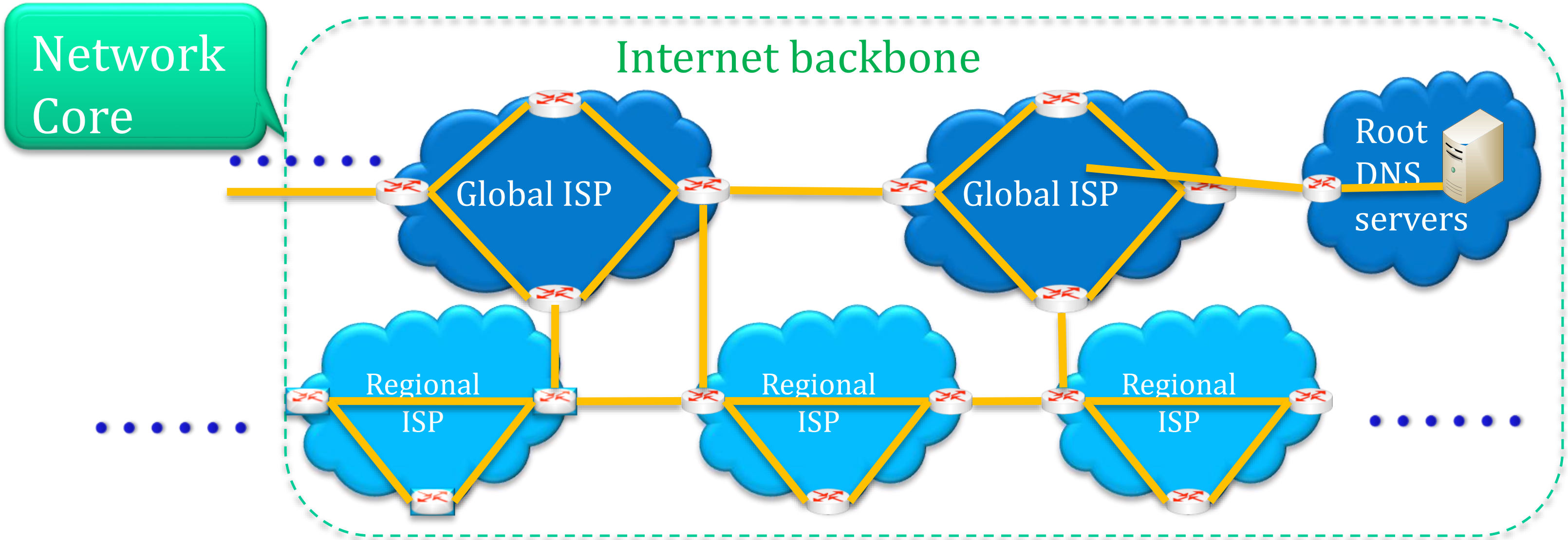
Network Core (1)



- Routers and fiber links (in orange) form the Internet core
- Routers work together to figure out the most efficient path for routing a packet from source to destination host
  - A distributed algorithm can adapt to changing Internet conditions
    - Great idea during the cold war
  - Routing tables are generated and maintained in real time

Network Core (2)



- The core is provided by ISPs that interconnect multiple continents
- ISPs
  - Global ISPs or Tier-1 ISPs
  - Regional ISPs or Tier-2 ISPs

Interconnected network of networks (1)

- Internet Backbone connects tier-1 ISPs
  - e.g., Verizon, Sprint, AT&T, Qwest, Level 3 Communications
  - The backbones of tier-1 ISPs are interconnected at various access points called Internet eXchange Points (IXP)
  - There were approximately 300 IXPs around the world (August 2009)
    - 83 in the U.S (the most IXPs in a country)
    - 86 countries have IXPs

Internet eXchange Point (IXP)

Source: https://prefix.pch.net/applications/ixpdir/

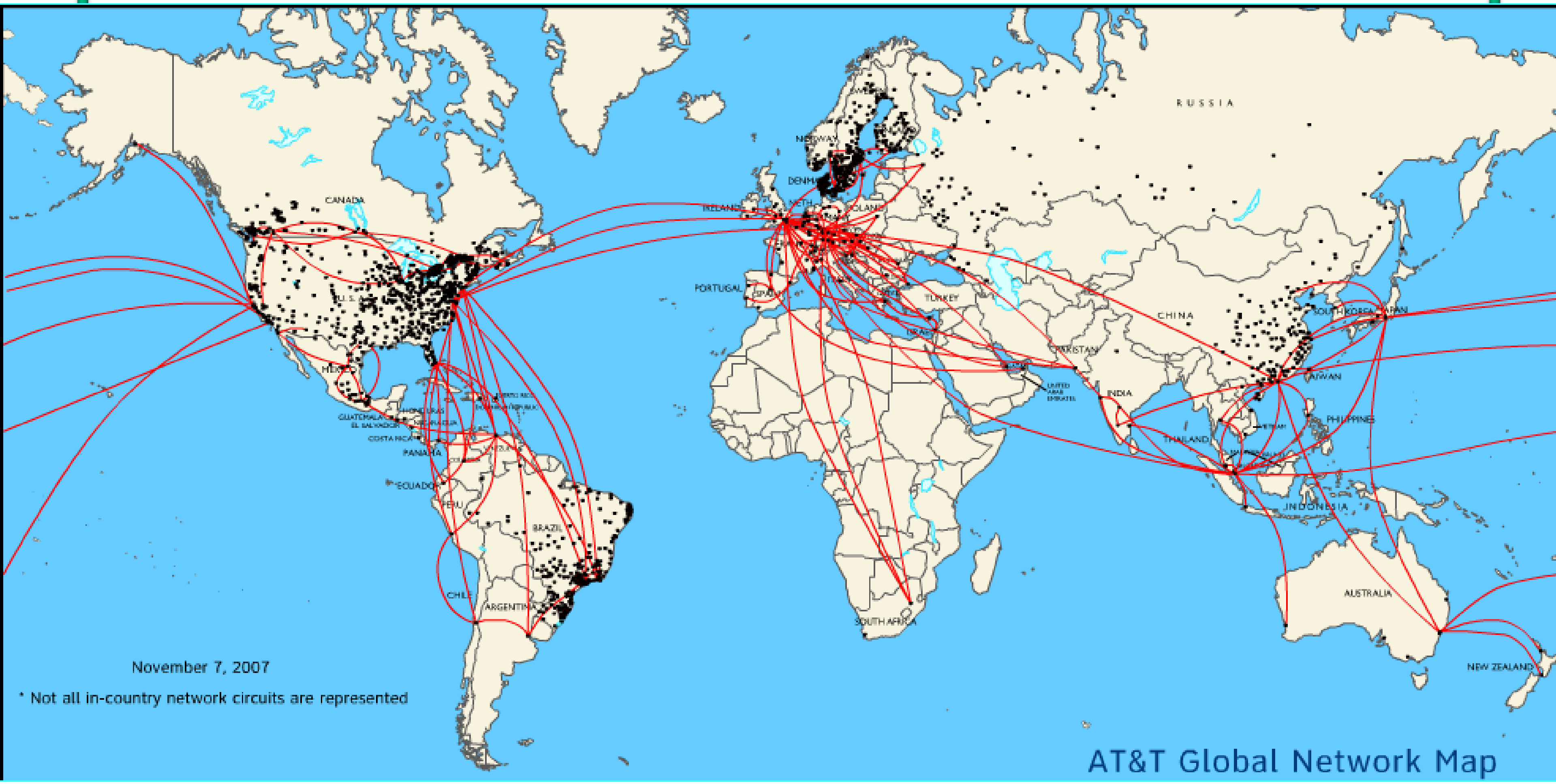
Interconnected network of networks (2)

- Public Peering
  - At these IXPs, major ISPs accept traffic from each other and agree to carry the other's packets to their downstream destination point without charge
  - Peering arrangements are made with bilateral and multilateral agreements between the carriers
- Private Peering
  - Major ISPs also have private peering agreements between each other in locations where two or more carriers have switching points in close proximity

IXP

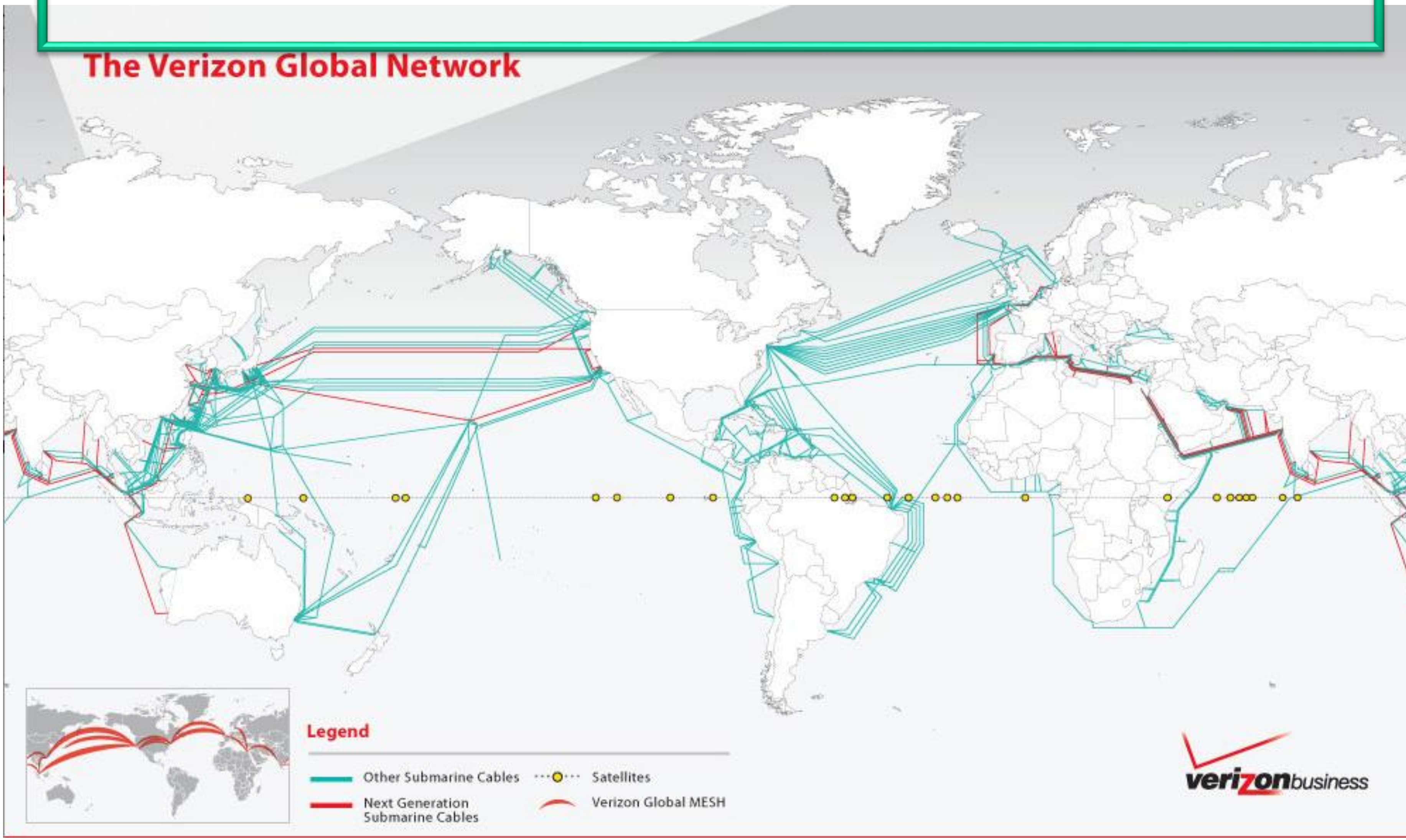
- IXP capabilities
  - Typically contains a centralized Ethernet Switching fabric and the necessary supporting infrastructure to enable companies to connect and peer at speeds ranging from 1 Gbps to multiples of 10 Gbps
  - Power: AC and DC, Generator, UPS
  - Fire Protection: Pre-Action, early warning
  - Monitoring: Mission Critical Systems, surveillance, access control
- E.g., one IXP is located at 56 Marietta St, NW, Atlanta, GA 30303

AT&T backbone

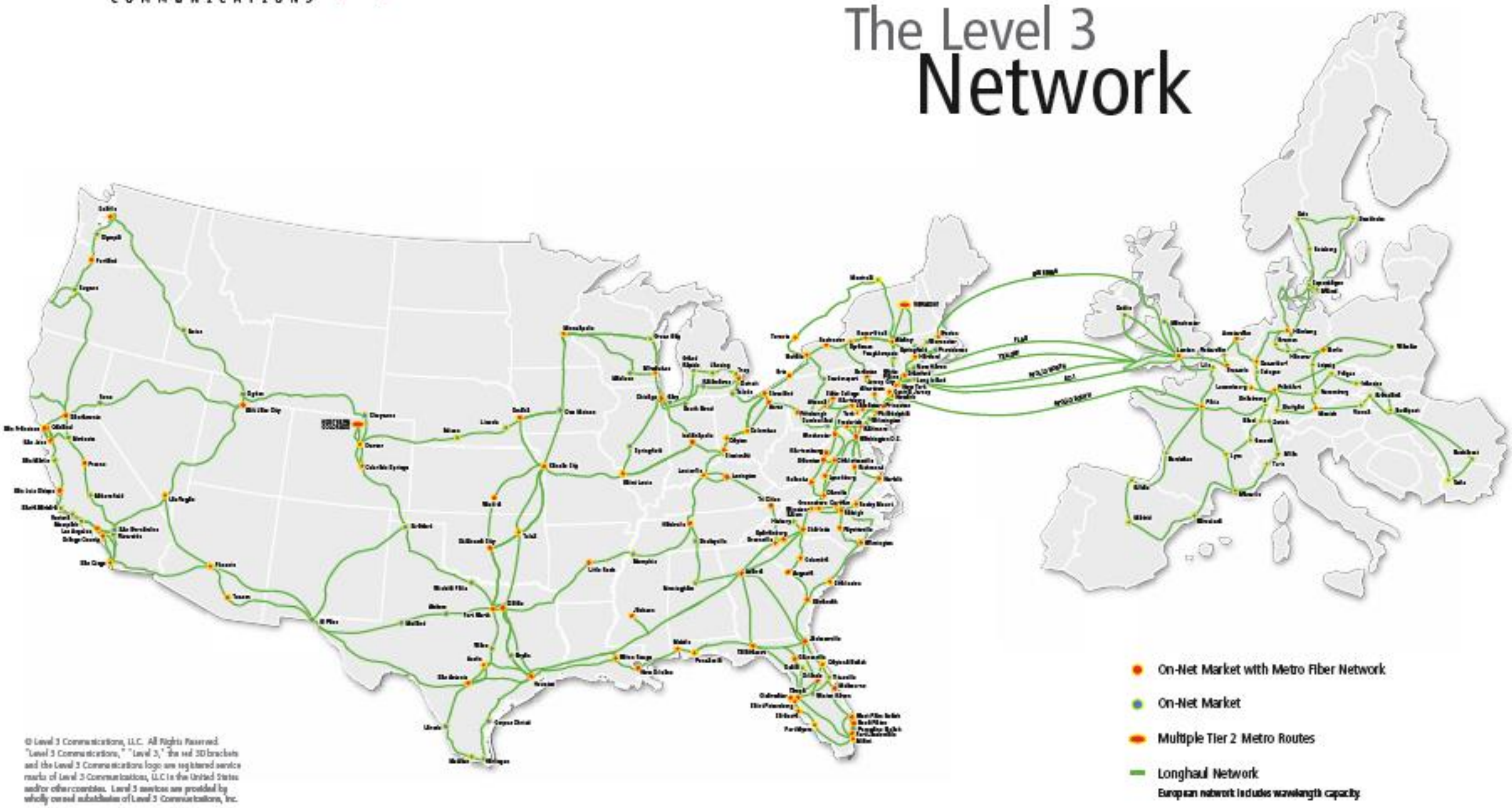


Source: http://www.corp.att.com/globalnetworking/media/network_map.swf

Verizon backbone



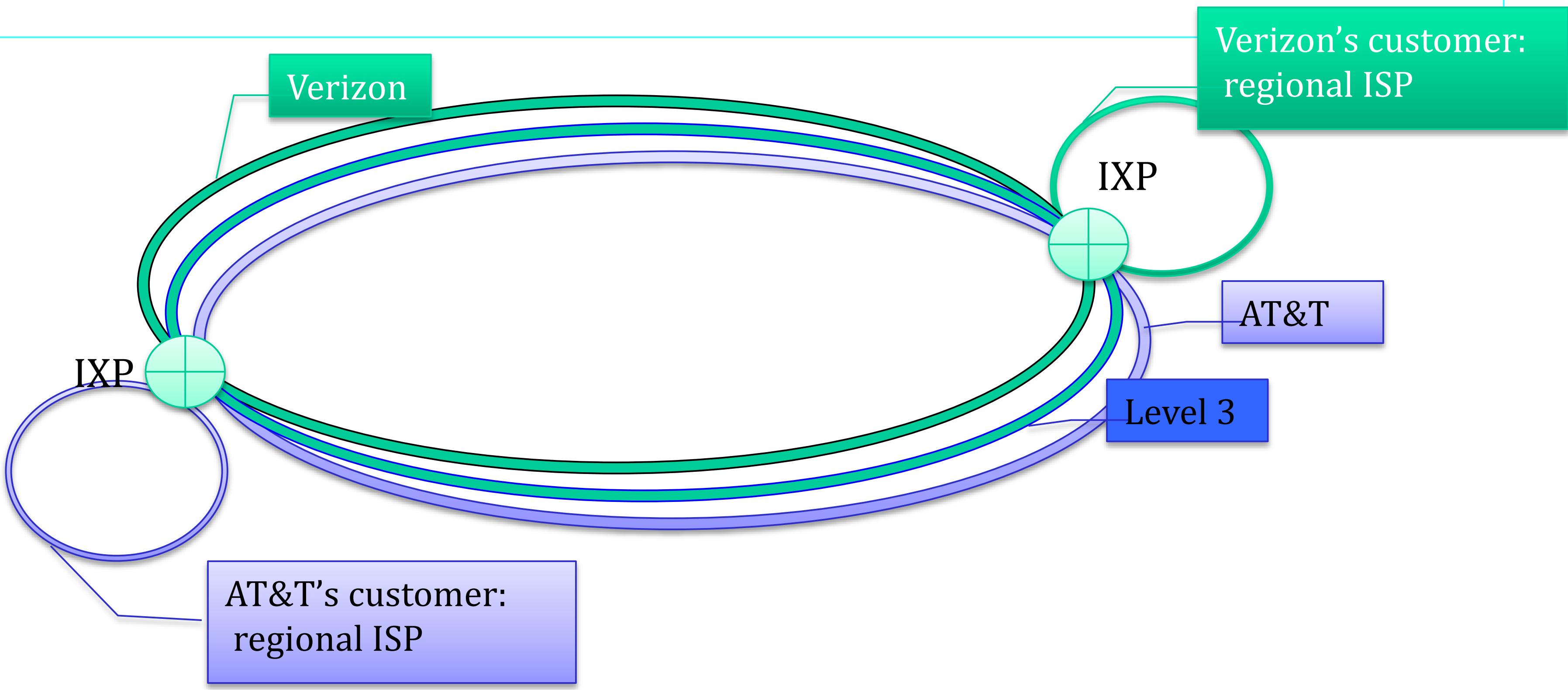
Source: http://www.verizonbusiness.com/us/about/network/



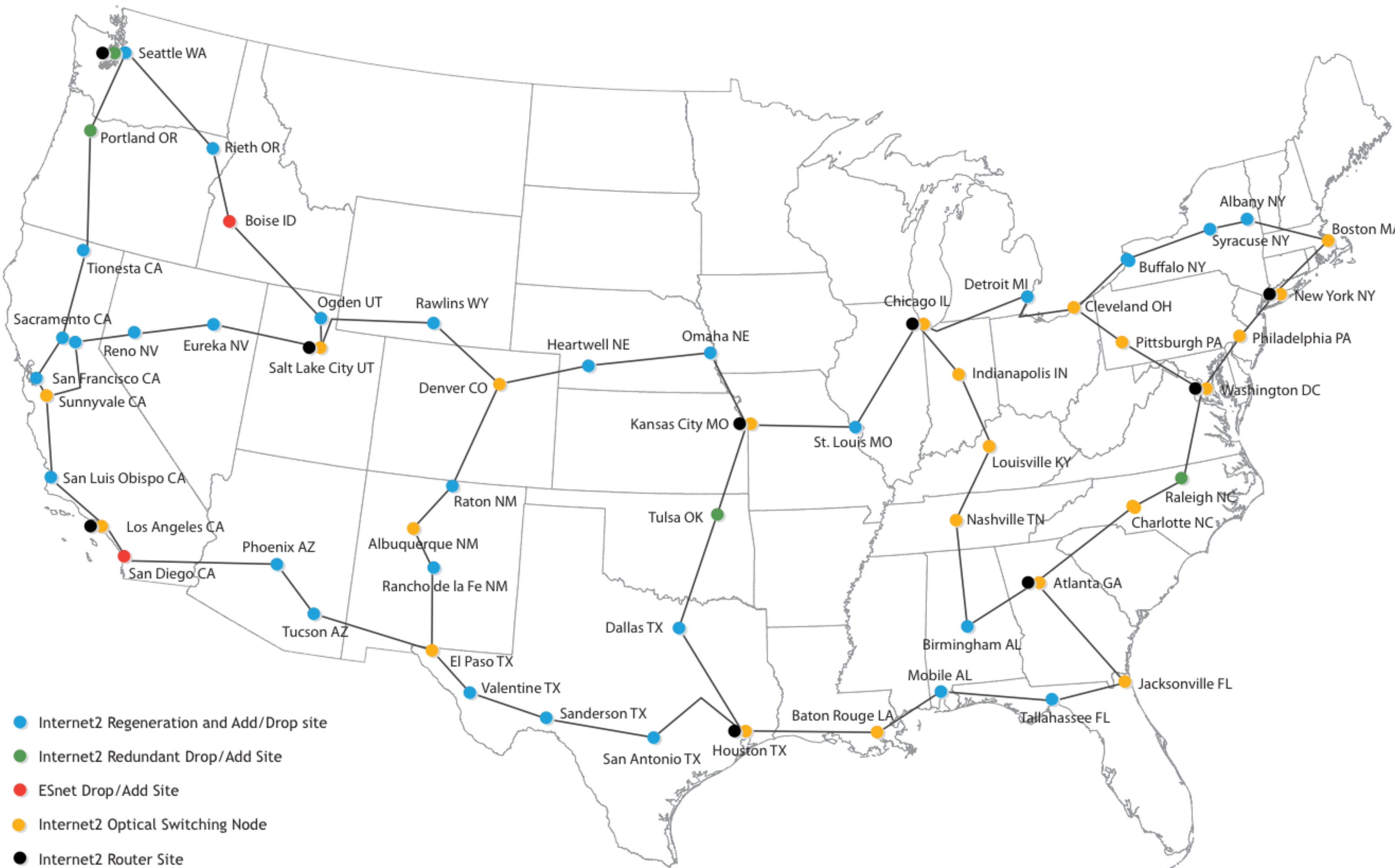
Source: http://www.level3.com/downloads/Level_3_Network_map.pdf

Hierarchical ISPs

- Regional ISPs: Tier-2 ISPs
  - Customer of Tier-1 ISP
  - Connect to one or more tier-1 ISPs, possibly to other tier-2 ISPs



Internet2 (internet2.edu)



Internet2

- Internet2 provides the U.S. research and education community with a hybrid optical and packet network
  - Funding through a federal stimulus grant via the National Telecommunications and Information Administration.
  - The IP network is built across a carrier-class infrastructure and supports leading edge IPv4, IPv6, multicast, and other advanced networking protocols
    - Services enabled by the Dynamic Circuit (DC) Network include short-term, point-to-point circuits, setup by the requestor or application in standard Synchronous Optical Network(SONET) bandwidth increments
    - Static networks are provisioned either by Internet2 over the Internet2-controlled optical infrastructure or by Level 3 Communications, on their nationwide network
  - Internet2 announced 11/15/2010 it will begin deployment of a new, nationwide 100 Gigabit per second (Gbps) Ethernet backbone network using 100 Gbps core routers
    - Complete deployment of this new network will occur in 2013
    - Partnership with Juniper Networks

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A distributed information sharing and delivering service

- Internet enables distributed applications/services:
  - Data sharing/service: Web, email, games, e-commerce and file sharing
  - Real-time service/delivery: VoIP, video conferencing and IP TV
- Transport services provided to applications
  - Reliable data delivery from source to destination
    - More overhead
    - Good for data, such as email
    - Cannot tolerate error and loss
    - Can tolerate delay and jitter
  - Best effort (unreliable) data delivery
    - Less overhead
    - Good for voice and video
    - Can tolerate error and loss
    - Cannot tolerate jitter

Information switching

- Data transfer in the Internet
  - Packet switching
    - Header contains source and destination IP address
    - Best-effort delivery
      - Packets may be lost
      - Packets may be corrupted
      - Packets may be delivered out of order
  - Circuit switching
    - Dedicated circuit per call: dial-up modem
    - Virtual circuit:
      - Classical IP over ATM
      - Leased lines

Analogy:
Circuit switching: a traveler paid a round trip ticket with reserved seats
Packet switching: an airline employee uses free, open tickets to fly (no reserved seats)

Circuit Switching

- End-to-end resources reserved for a connection
  - Establish a connection before data transfer
  - Circuit-like (guaranteed) performance
- Dedicated link bandwidth, and switch circuit capacity
  - Dedicated resources: no sharing
    - Using FDM, TDM or ATM (virtual circuit switching)
    - Resource is idle if not used by the call's owner
    - No queueing delay
  - Call setup and teardown required
  - E.g., modem or CBR (Constant bit rate) ATM for leased lines

Example for circuit switching

- How long does it take to send a message of 1,000,000 bits from host A to host B over a circuit-switched network?
  - All links are 1.536 Mbps
  - Each link uses TDM with 24 channels or slots
  - One channel is used for this transmission
  - 500 msec to establish end-to-end circuit
  - Propagation delay = distance/propagation speed = $2x10^5$ m/$2x10^8$ m/sec = 1 msec
  - 0 queueing delay

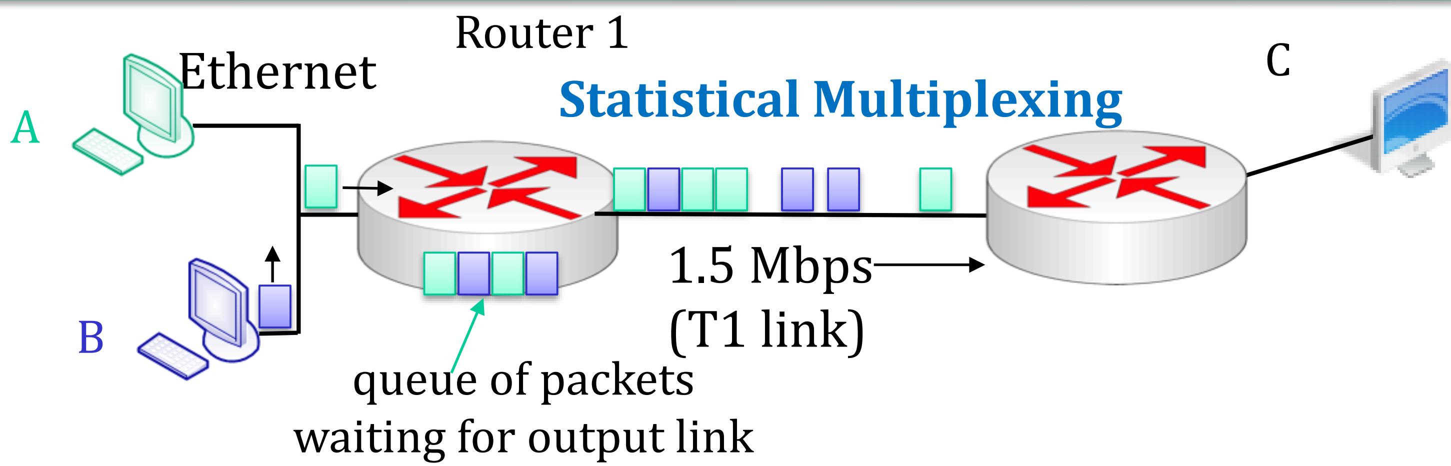
Total delay = transmission delay + setup delay + propagation delay =

$1,000,000/(1.536x10^6/24)$ + 500 msec + 1 msec= 16.126 sec

Packet Switching

- The base of the Internet
  - Invented by Leonard Kleinrock, 1961
- Each host data stream is segmented into packets
- Destination IP address is in the packet header
  - Analogy: envelope address
- Each packet travels by itself using available resources provided by routers
- Packets may be lost while traveling
- Received packets may be out of order
- Transport layer must put the received packets in the correct order and reassemble them at destination

Statistical Multiplexing

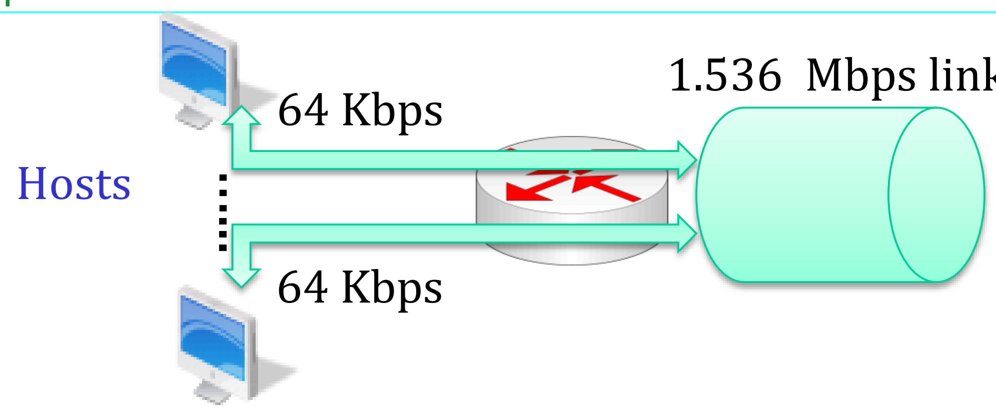


- Packet switching is based on statistical multiplexing
  - Packets are sent by hosts A and B
  - If there is no priority set, then every packet is treated the same based on the order of arrival
  - Router 1's T1 link bandwidth is shared by packets from hosts A and B
- In contrast, FDM and TDM let each host use the same slot and there is no resource contention

Packet switching versus circuit switching

- Assume a 1.536 Mbps link is the connection to the Internet
- Each host:
  - 64 Kbps when "active"
  - Active 20% of time
- Circuit-switching
  - Can serve 24 hosts
- Packet switching
  - May serve 120 (24*5=120) hosts or even more statistically
  - May have a chance to upset some hosts due to contention

Packet switching may serve more hosts with some uncertainty



Packet switching versus circuit switching (1)

- Packet switching is great for bursty data
  - Best effort delivery
  - Better for resource sharing
  - Network congestion
    - Packet delay in the router’s queue
    - Packet loss due to queue overflow
  - Protocols need to pay overhead for reliable data transfer, congestion and flow control
    - Analogy: Freeway uses traffic light to control the entrance in order to control congestion

Packet switching versus circuit switching (2)

- Circuit switching is great for voice and video
  - Bandwidth guarantee
  - Timing, latency, and latency jitter guarantee
  - Complex mechanisms lead to high cost for equipment and management
    - Most enterprise networks replaced ATM LANs with Gigabit or 10 Gbit Ethernets

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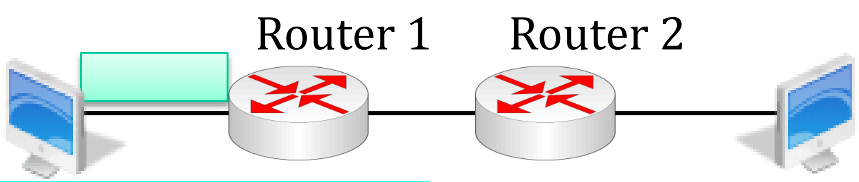
Latency in packet switching network

Packet length: L bits
Link Rate: R bps



- Store and forward packets in a router
- If the link is available, it takes L/R seconds to transmit one packet from Router 1 to Router 2
  - Transmission delay
- Assuming store and forward routing, entire packet must arrive at one router before it can be transmitted on the next link
- Host to host delay = 3L/R + propagation delay + other delays

- Example:
- L = 1000 Mbits
- R = 100 Mbps (Ethernet)
- transmission delay per link = 10 sec
- Total transmission delay = 30 sec

Congestion and Flow control (1)

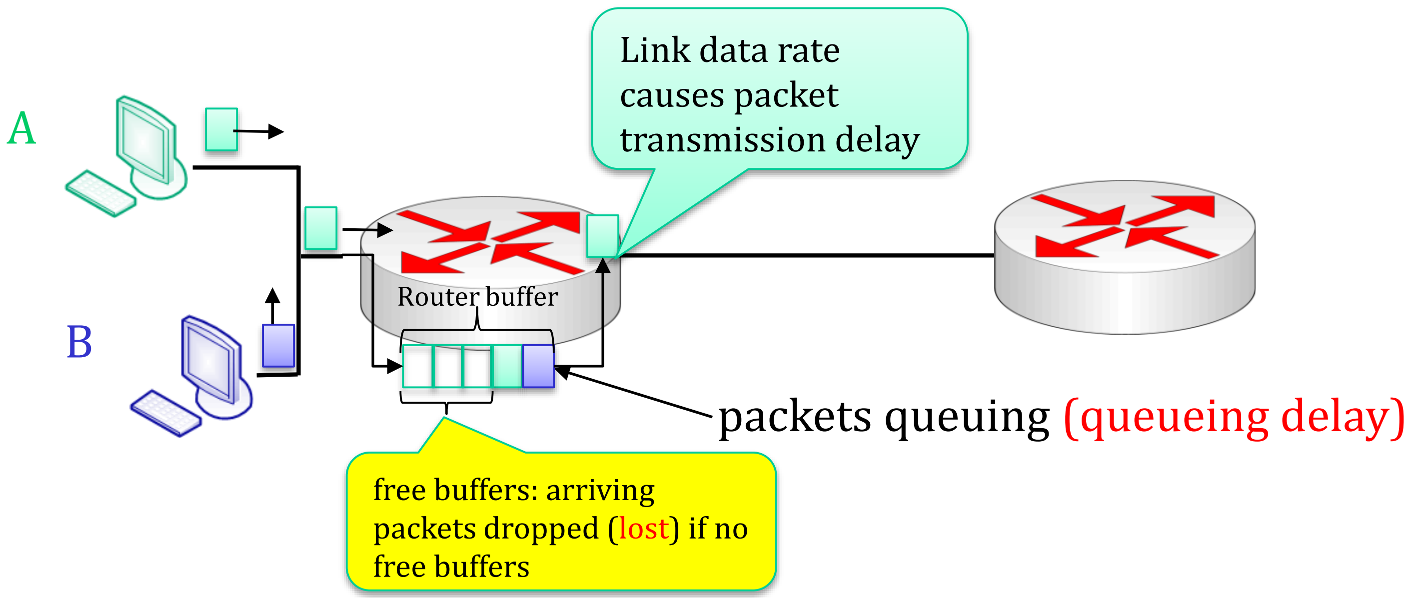
- Source host sends out too much information
  - Destination host cannot digest
    - Server has better CPU, huge buffer and faster link
    - Smartphone has a low-power CPU and slower link
  - Busy link
  - Router/switch buffer overflow
- Loss and delay causes packets to be resent in TCP
- Negative feedback causes even more congestion
- Congestion control throttles the output rate of source hosts to relieve congestion by using the symptom of congestion
  - Packet loss
  - Packet delay
  - Buffer overflow

Congestion and Flow control (2)

- Flow control tells the source host how much information that destination host can digest
  - Server has
    - Powerful CPU
    - Vast memory
    - 1 or 10 Gbps link
  - Client: smart phone has
    - Batter-powered CPU
    - very little memory
    - Low-bandwidth link
- Goal: to optimize the throughput rate (bits/sec) between source and destination

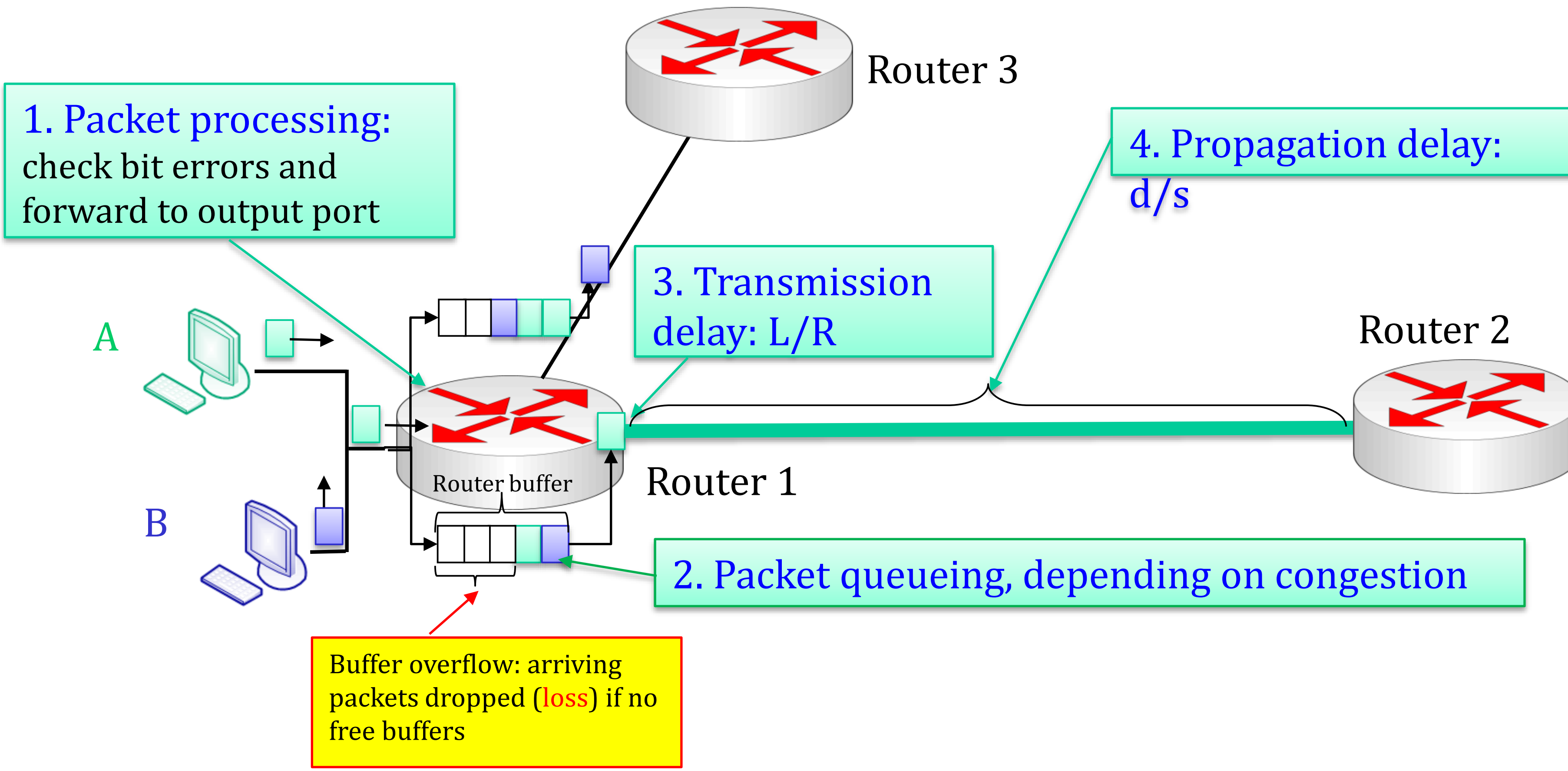
Packet loss and delay

- Packets queue in router buffers
  - Waiting for available output link with a finite pipe
  - Packet arrival rate exceeds output link capacity
    - packets queue, and wait their turn
  - If the downstream links are busy (congested), queueing delay will be dominant
- If there is no free queue (buffer) space, arriving packet is dropped (packet loss)

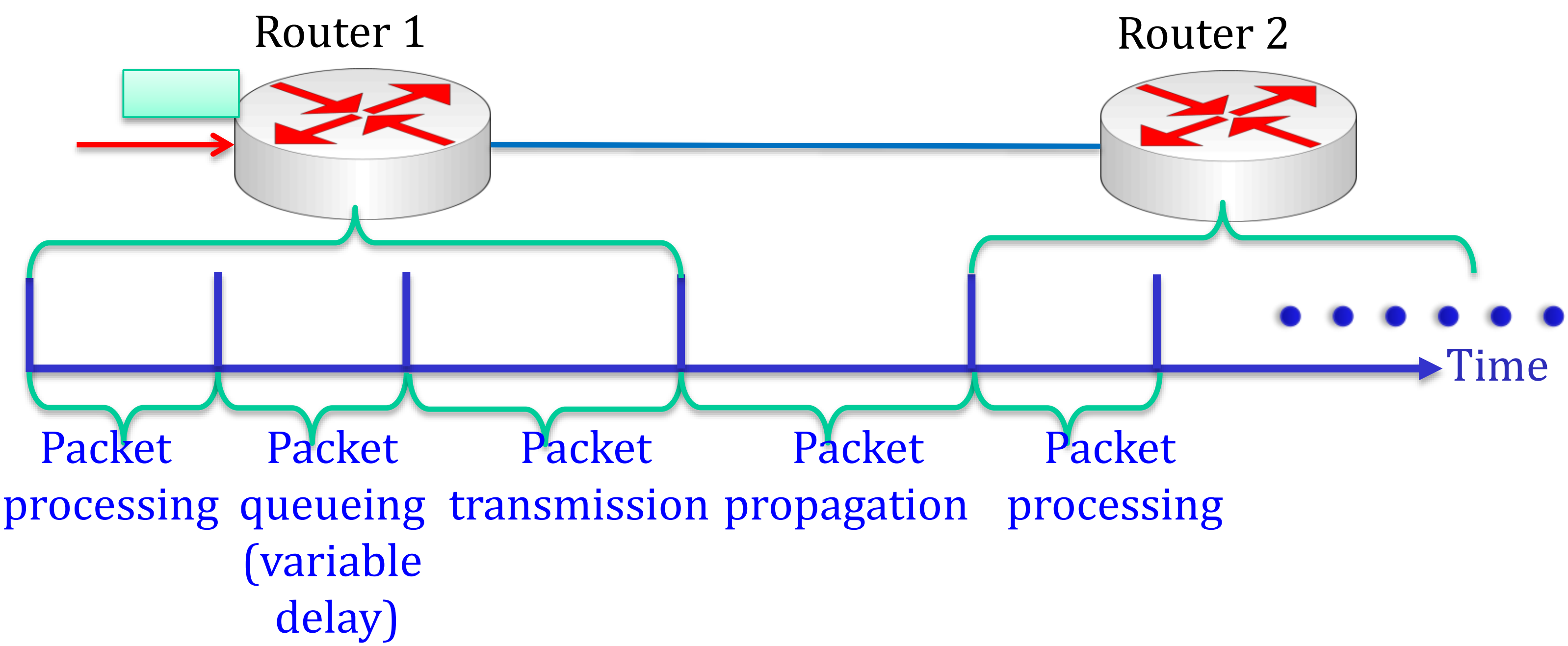


4 packet delay factors

Total Delay of a node = processing delay + transmission delay + propagation delay + queueing delay



Router Delays



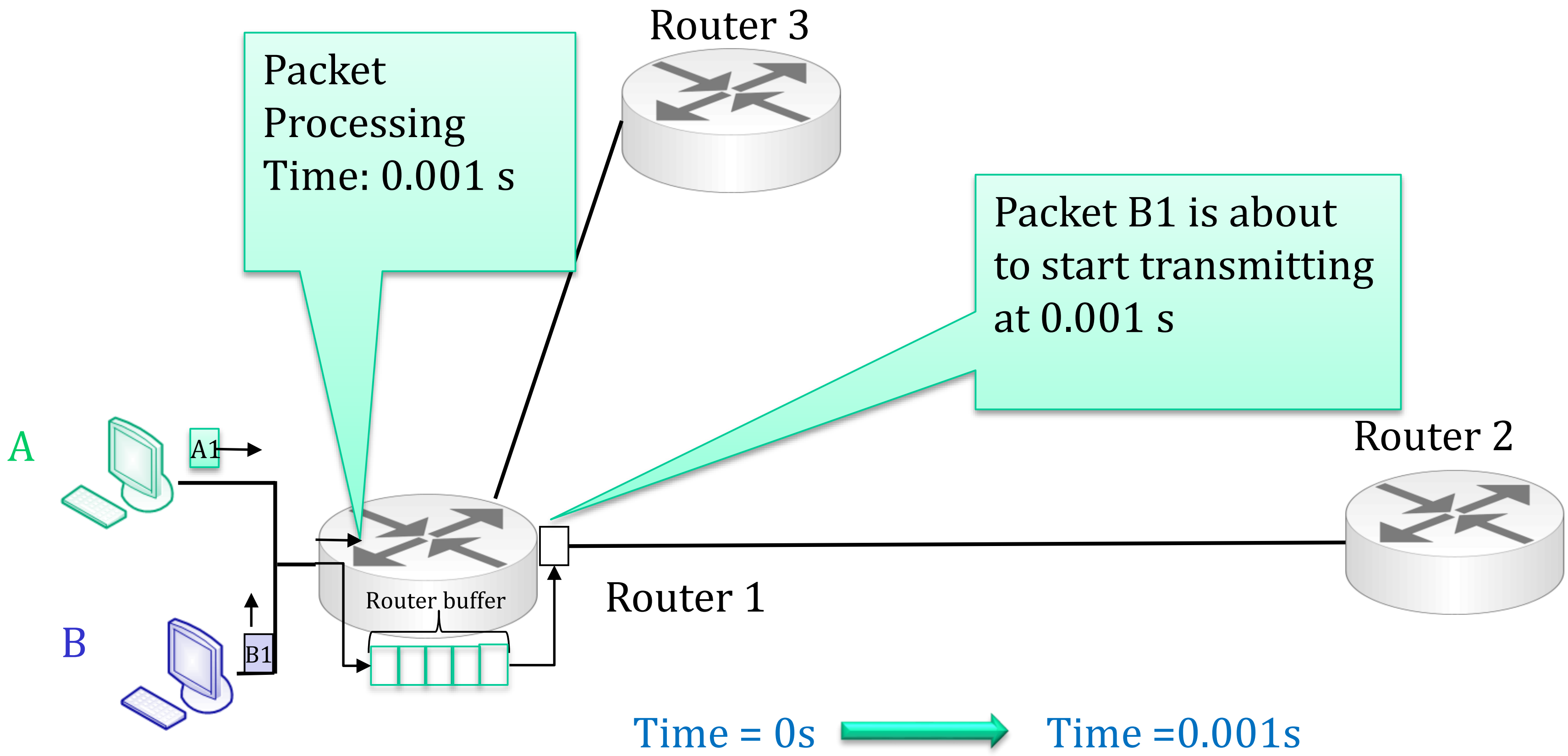
Packet switching cannot maintain the order of the packets

- When packets travel in the Internet, they must pass through many routers
- Today's Internet backbone routers typically employ multi-threaded network processors or application-specific integrated circuits (ASICs) for forwarding processing
- Each router processes multiple packets in parallel and it is impossible to make sure that the output packets have the same order as the input packets due to parallel processing
- Hence packet switching cannot maintain the order of the packets when a message contains multiple packets

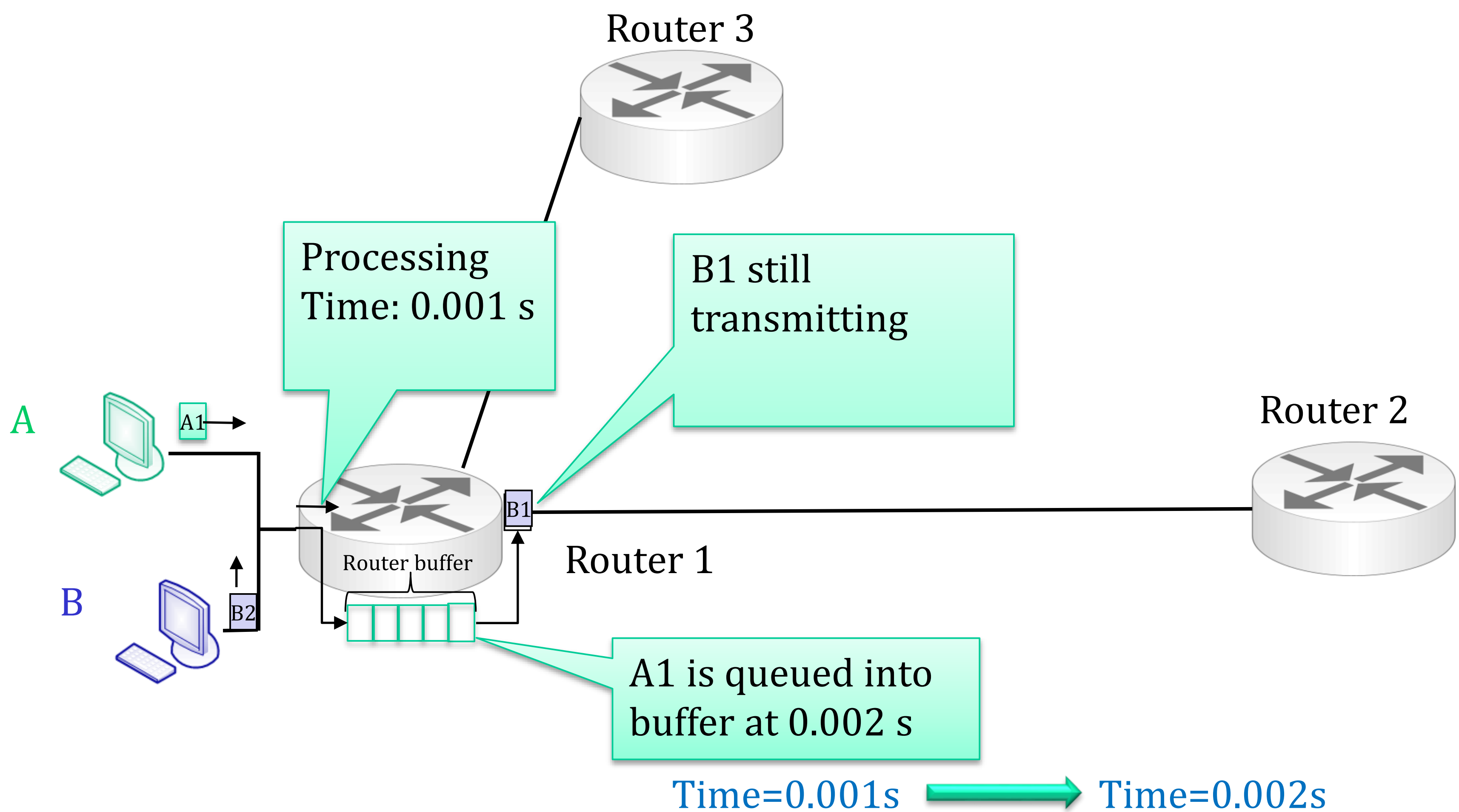
Example

- Packet length L = 7 Kbits
- Link rate R = 1 Mbps
- Propagation speed s = 2×10^8 m/sec
- Distance between routers d = 2×10^5 m
- Propagation delay = d/s = (2×10^5 m)/ (2×10^8 m/sec) = 0.001 s
- Transmission delay = L/R = (7 Kbits)/(1Mbps)= 0.007 s
- Packet Processing Time = 0.001 s
- A has 4 packets to send (A1, A2, A3, A4)
- B has 5 packets to send (B1, B2, B3, B4, B5)
- Routers 1 and 2 have buffer space for 5 packets
- A and B have infinite buffer
- A and B have zero distance to the first router
- Assume best-effort Transmission

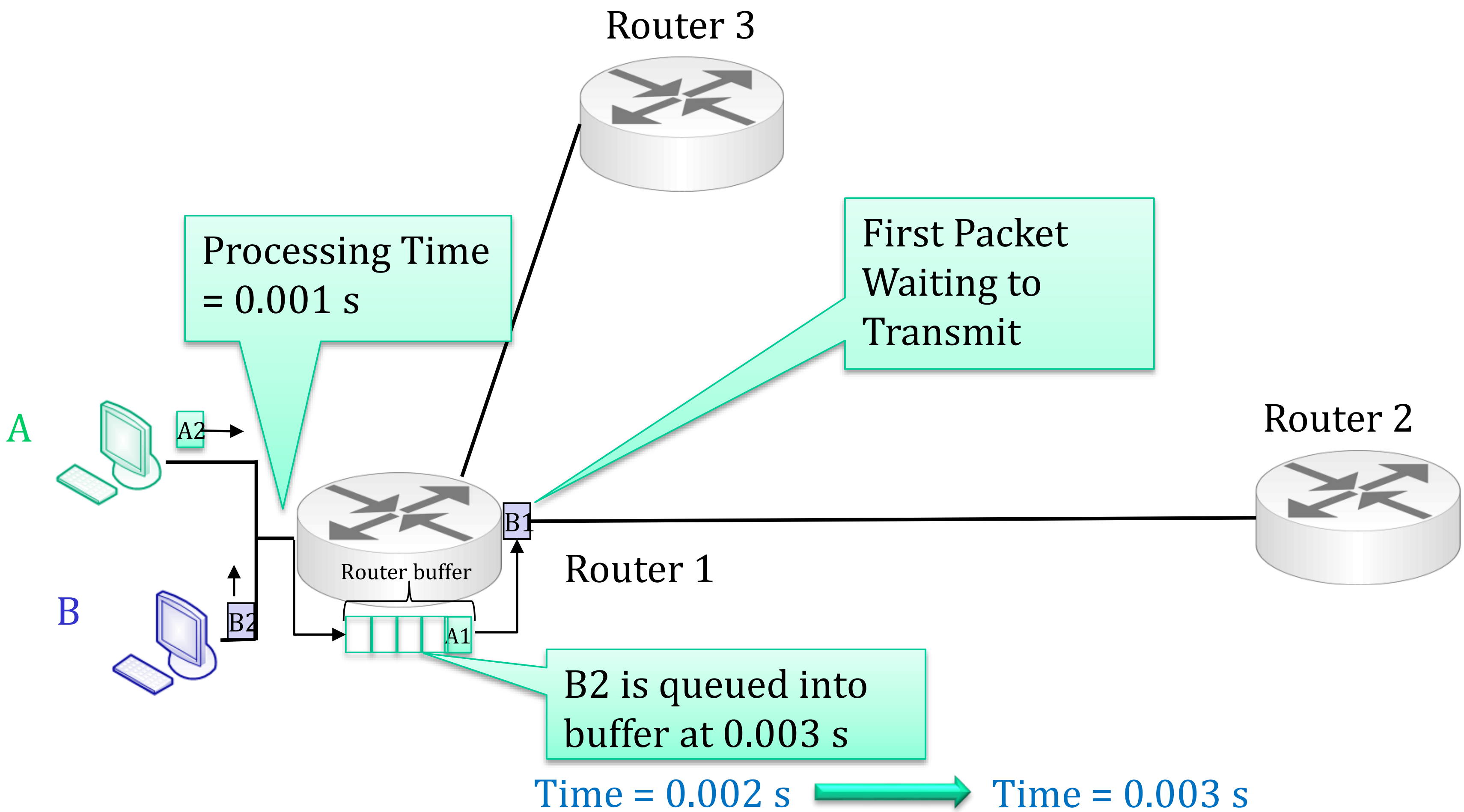
4 packet delay factors (1)



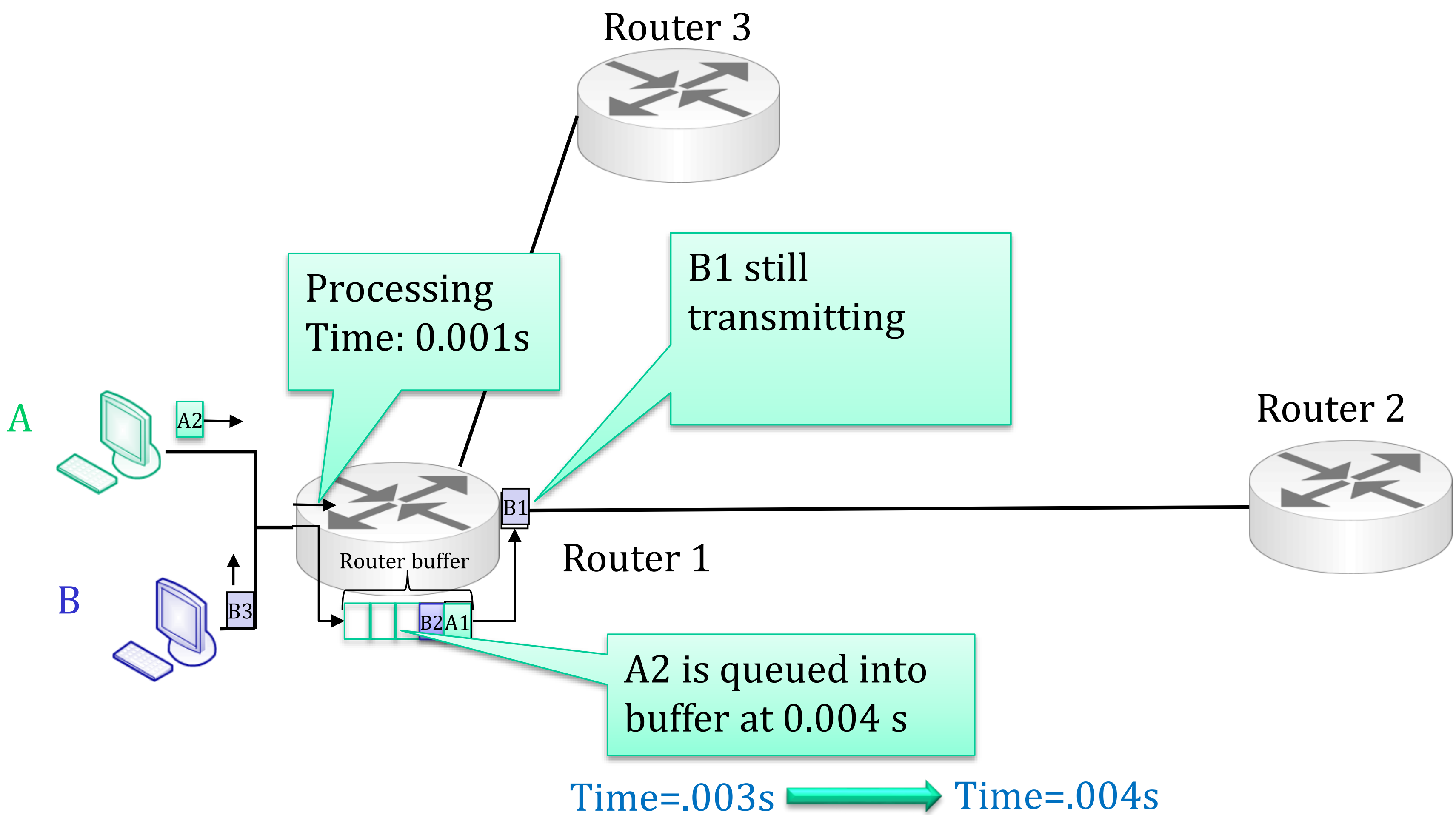
4 packet delay factors (2)



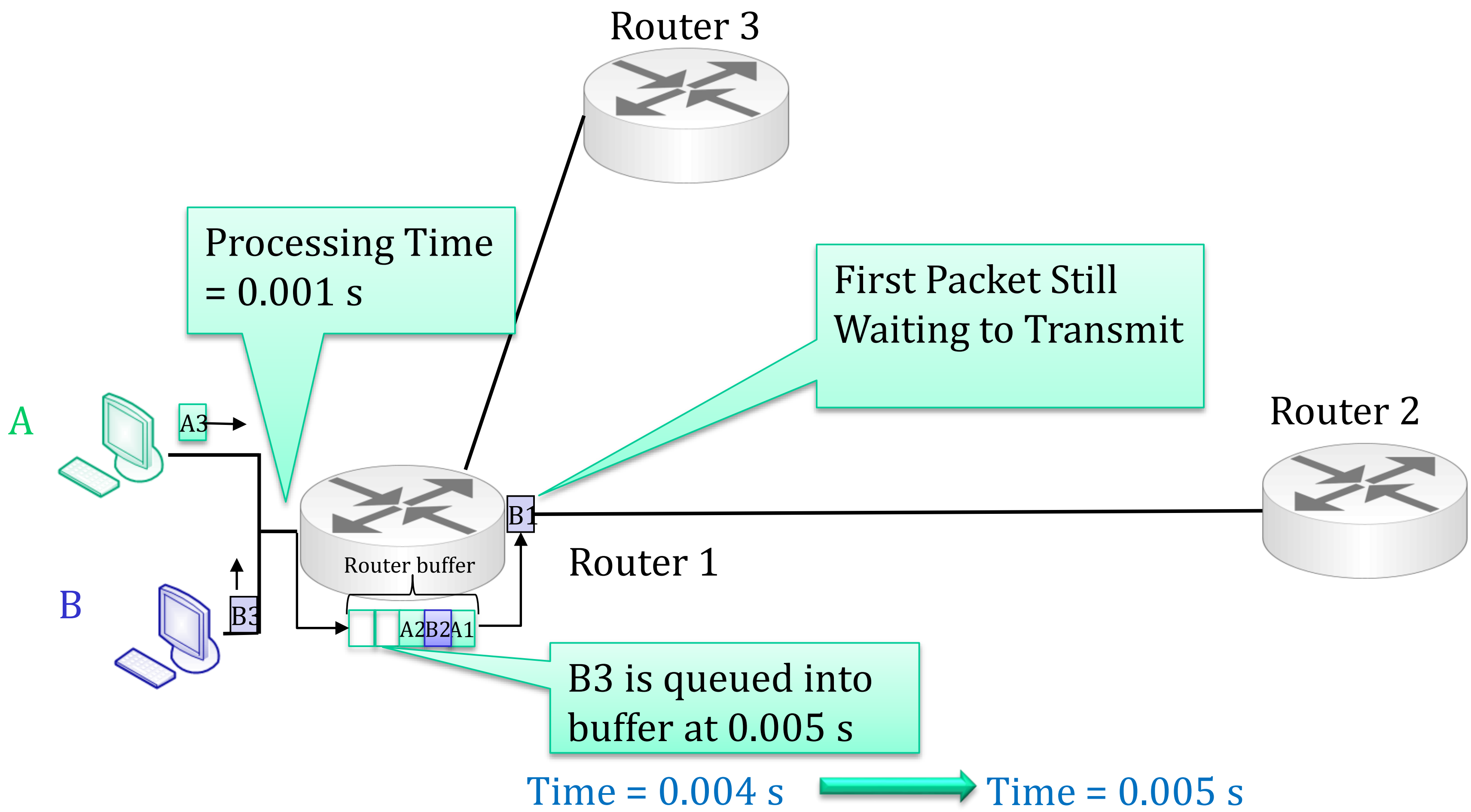
4 packet delay factors (3)



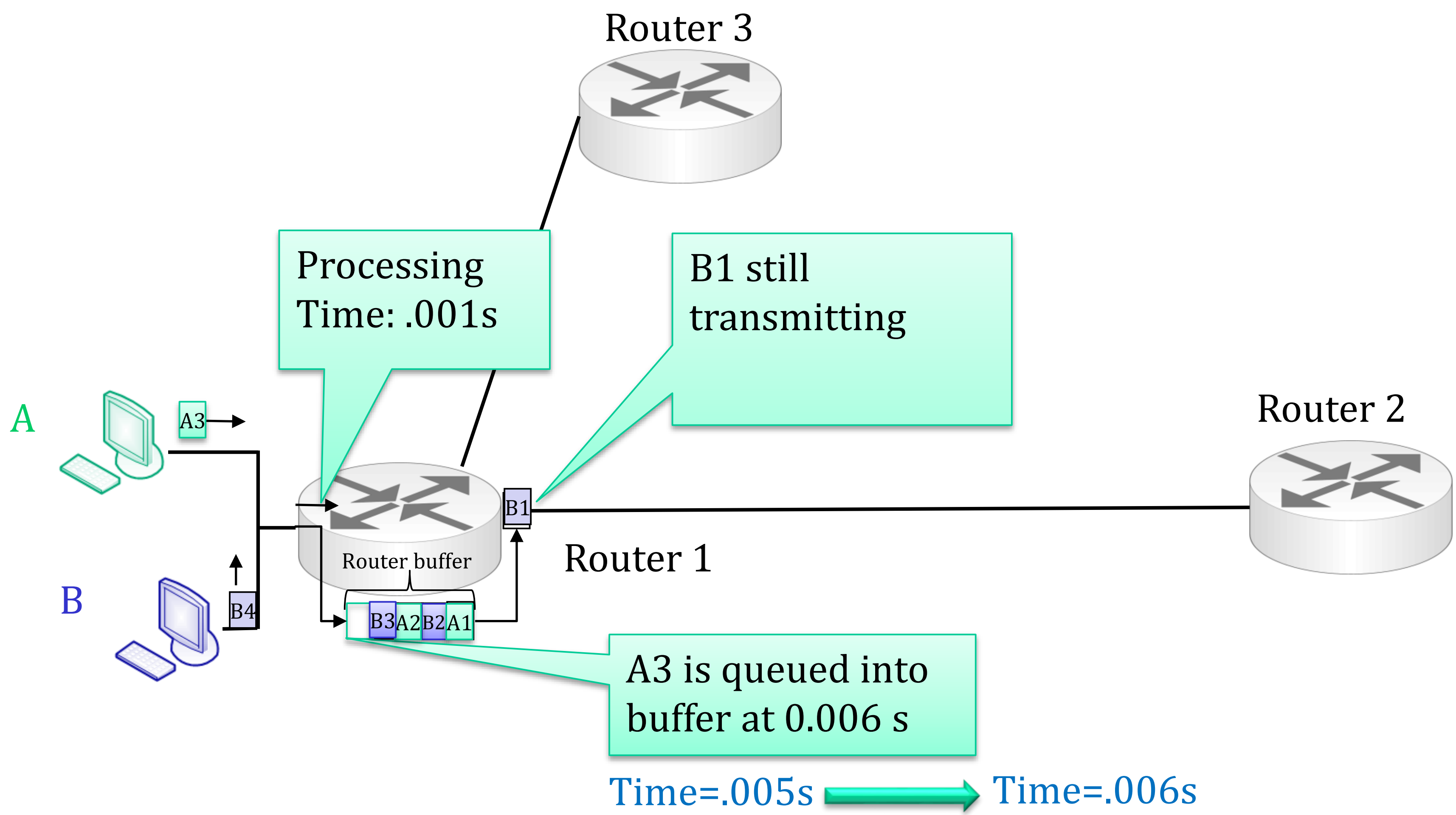
4 packet delay factors (4)



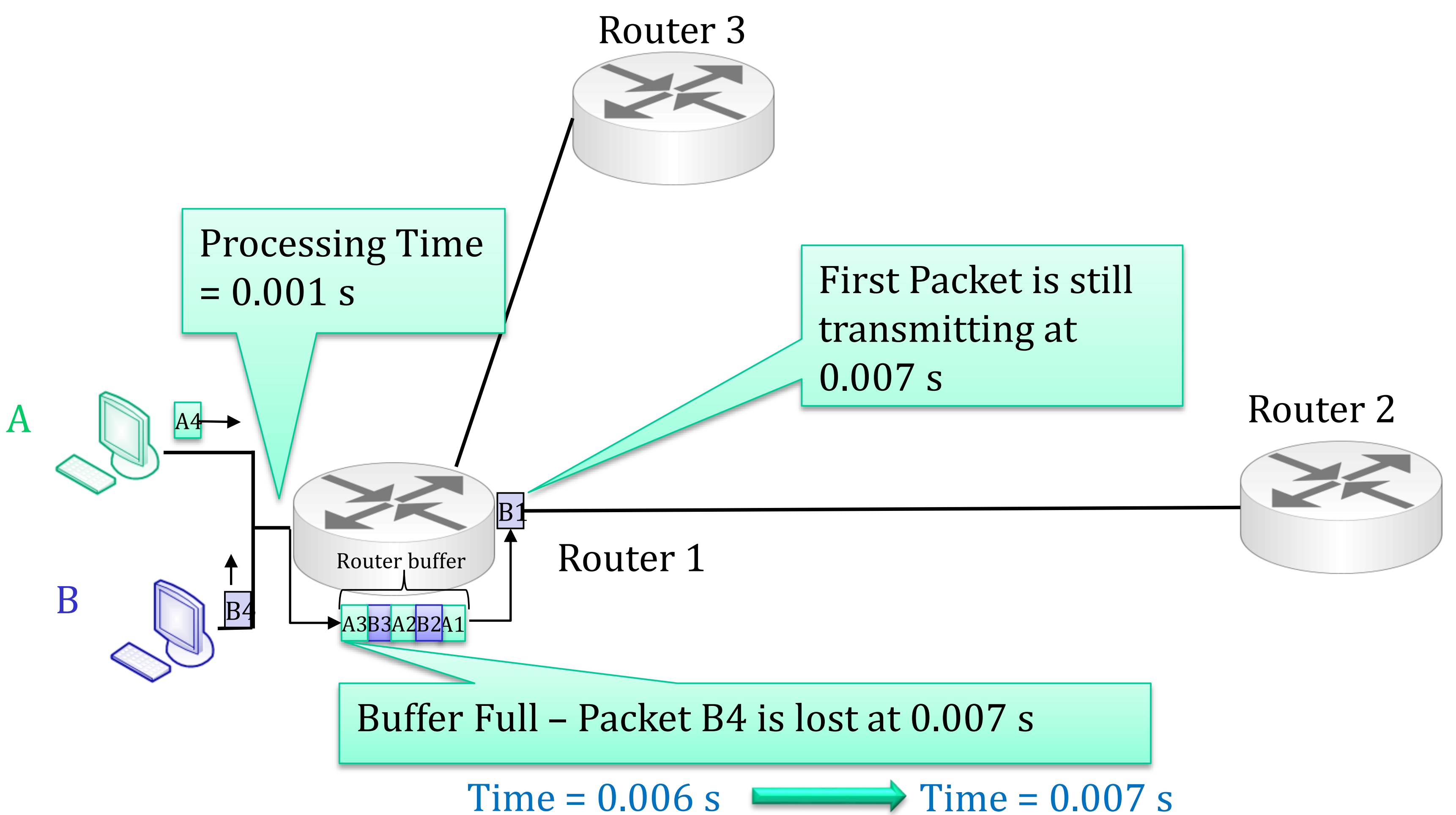
4 packet delay factors (5)



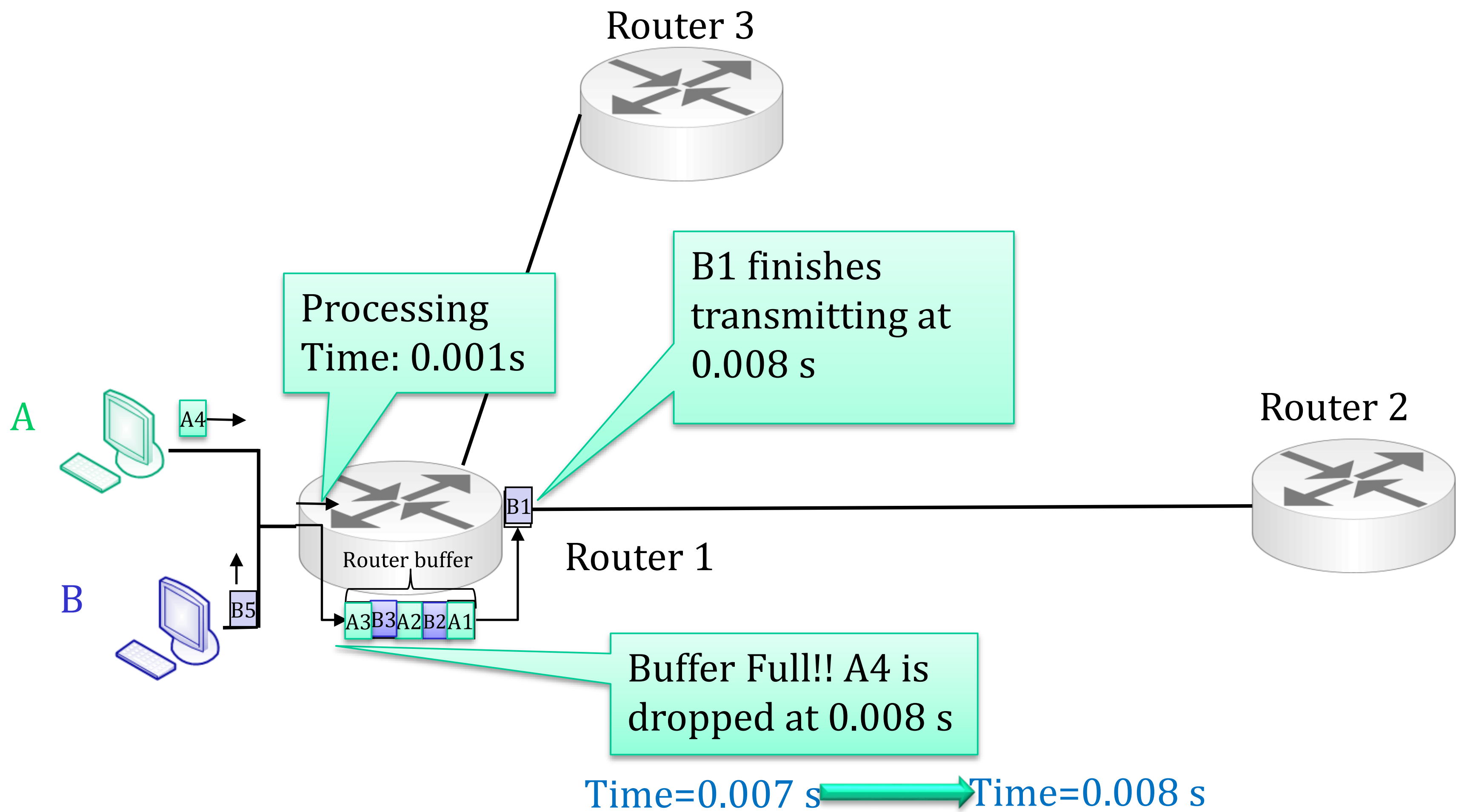
4 packet delay factors (6)



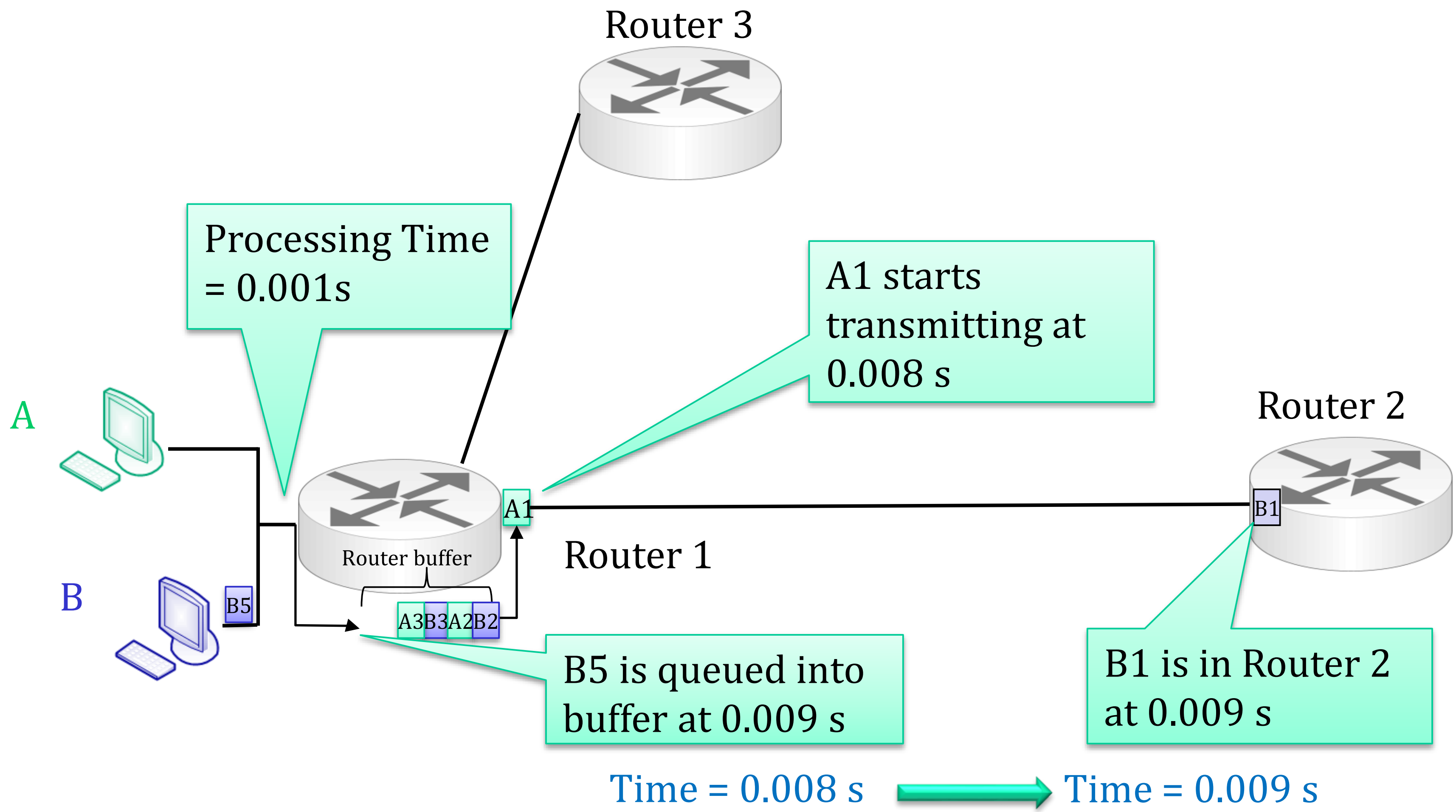
4 packet delay factors (7)



4 packet delay factors (8)



4 packet delay factors (9)



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Modularization by layering

- Develop Internet: Divide and conquer by many people
- Internet can be modularized by layers
- Modularization eases
  - Development (one company can tackle one module)
  - Maintenance
  - Updating the system
- Interaction between layers
  - Each layer relies on services from layer below
  - Each layer exports services to layer above
- Interface between layers defines interaction
  - Hides implementation details
  - Layers can change without disturbing other layers

Internet protocol stack: US DoD Model (1)

- Application Layer
  - Network applications
  - HTTP, SMTP
- Transport Layer
  - Process-to-process data transfer
  - Segment message at source and reassemble message at destination
  - TCP: reliable transport with overhead
    - Transmission Control Protocol
  - UDP: best effort delivery with little overhead
    - User Datagram Protocol
  - SCTP: reliable transport based on transaction
    - Stream Control Transmission Protocol

Application	Layer 5
Transport	Layer 4
Network	Layer 3
Data Link	Layer 2
Physical	Layer 1

Internet protocol stack: US DoD Model (2)

- Network Layer
  - Routing of datagrams from source subnet to destination subnet
  - IP, and routing protocols
- Data Link Layer
  - Data transfer between adjacent neighboring network nodes connected by a physical medium (copper, fiber or wireless)
  - Ethernet, WiFi
- Physical Layer
  - Bits propagate using copper, fiber and radio

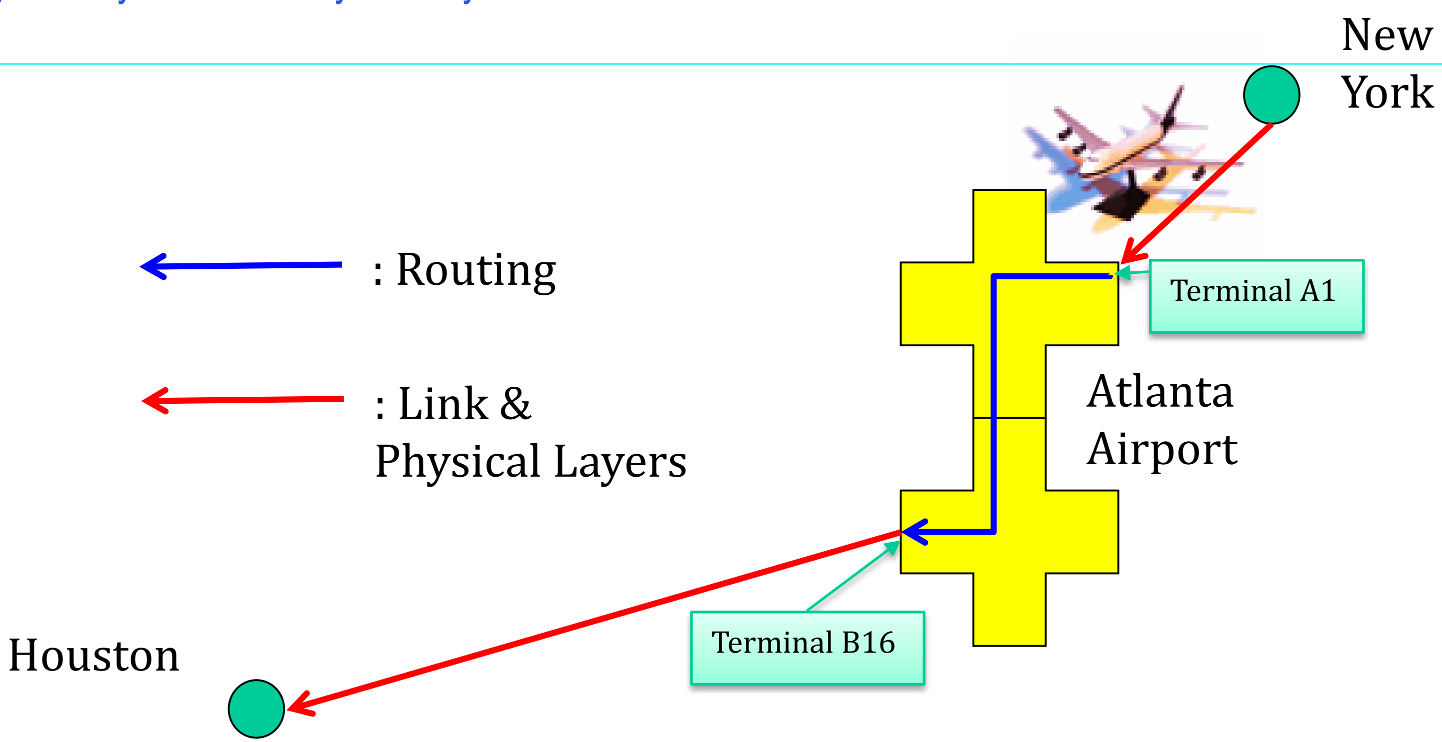
Application
Transport
Network
Data Link
Physical

Application Layer

- Web-based applications
  - Use scripts for rapid development
    - E.g., Javascipt for client side
    - E.g., PHP for server side
  - There are many other script languages, such as Perl, asp, Ruby, etc.
- New protocol or technology development
  - Sockets: an API for programmers to invoke TCP, UDP or SCTP
    - Extending the IPC (Inter Process Communication) to another host in the Internet
    - OS and Firmware/hardware support IPC
    - Information is virtually stored in the device's memory
  - Socket programming: using Java or C++
    - Applications invoke protocols to handle information exchange
    - Information is virtually present in memory with access latency and loss

Routing vs. Data Link layer

- Forwarding/Routing: moving from one terminal to another terminal for boarding next flight
  - Using flight number and monitor guide
- Data Link: flight from one airport to another
- Physical layer: invoked by Link layer



Physical Layer

- The Physical Layer defines the means of transmitting bits rather than packets over a physical link connecting network nodes
  - The bit stream may be grouped into code words or symbols and converted to a physical signal that is transmitted over a hardware transmission medium
  - The Physical Layer performs character/symbol encoding, transmission, reception and decoding
- Transmission Media
  - Copper: twisted pairs, coax
  - Fiber
  - Radio
- Encoding
  - The physical layer defines the representation of each bit/symbol as a voltage, current, phase, frequency, or photons

OSI reference model (International standard)

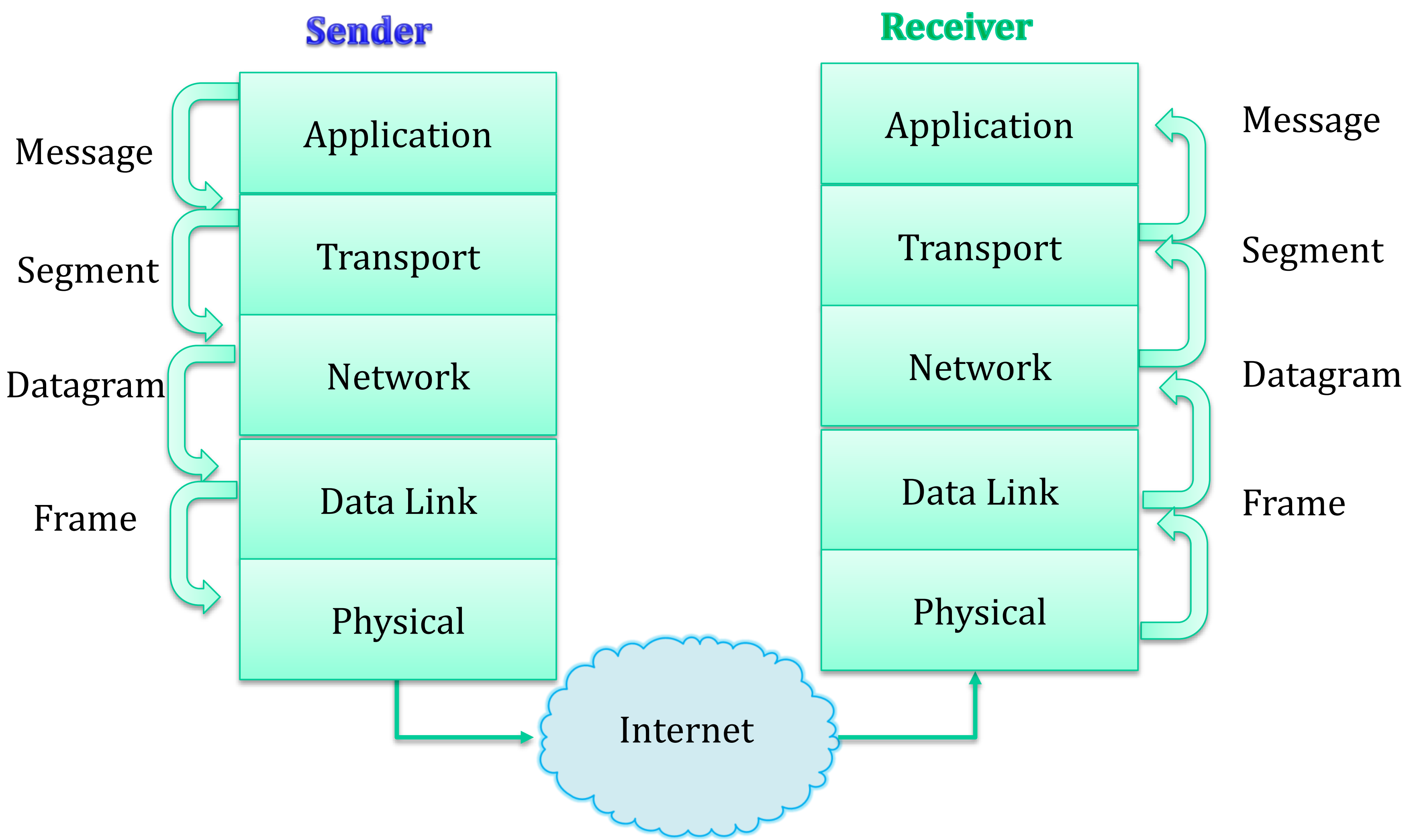
- OSI (open system interconnect) 7 layer model
  - US pledged to use OSI in 1980s
  - OSI was never finished
  - US DoD had sufficient funding to complete its protocol stack
- US DoD Internet stack does not explicitly modularize two layers
  - Presentation Layer
    - Allowing applications to deal with coding of data, e.g., encryption, compression and unicode
  - Session Layer
    - Grouping connections together for efficiency, synchronization, recovery or data exchange
  - These services, if needed, must be implemented in application layer in the US DoD model

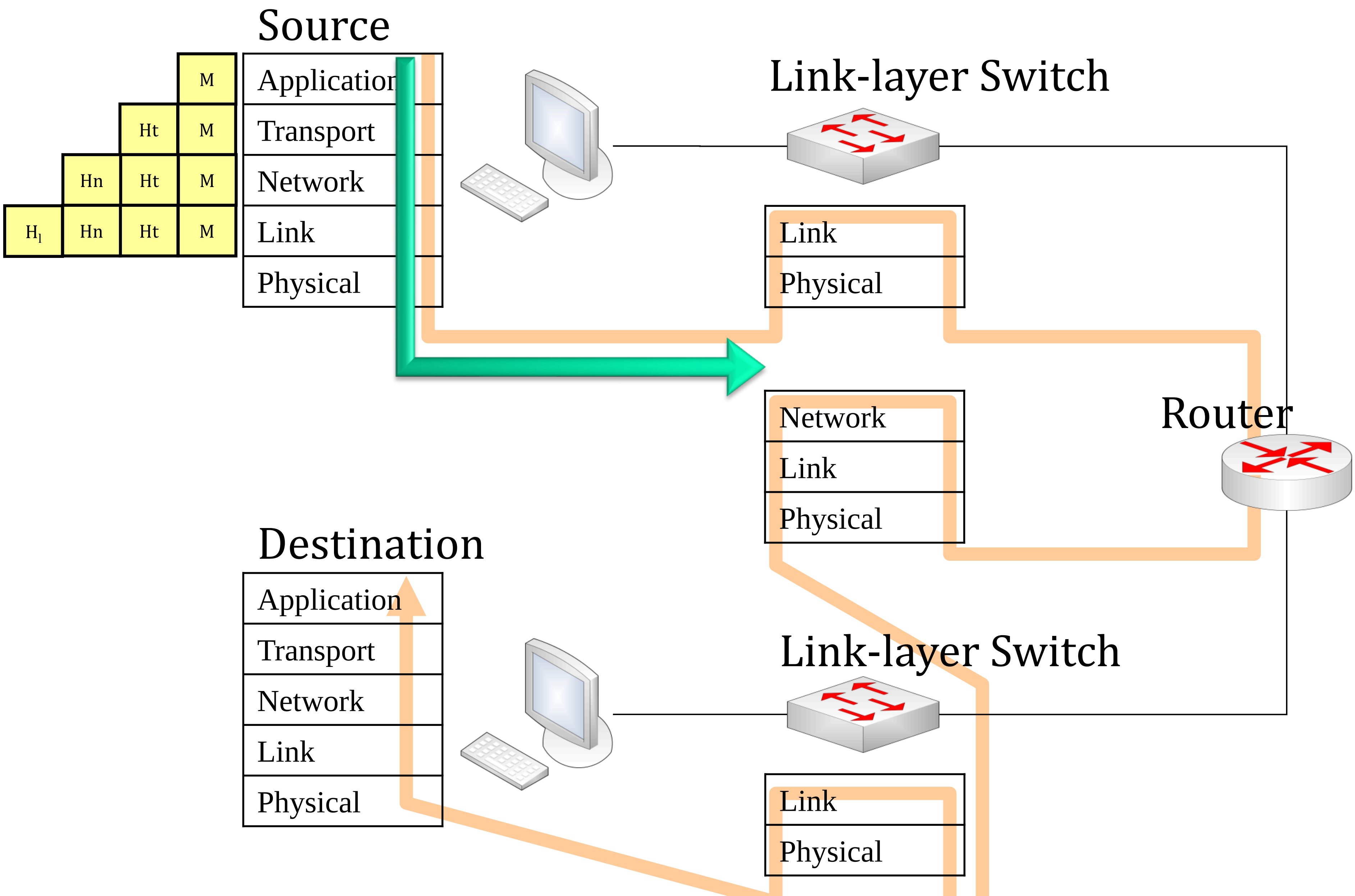
Application
Presentation
Session
Transport
Network
Data Link
Physical

Header for each layer

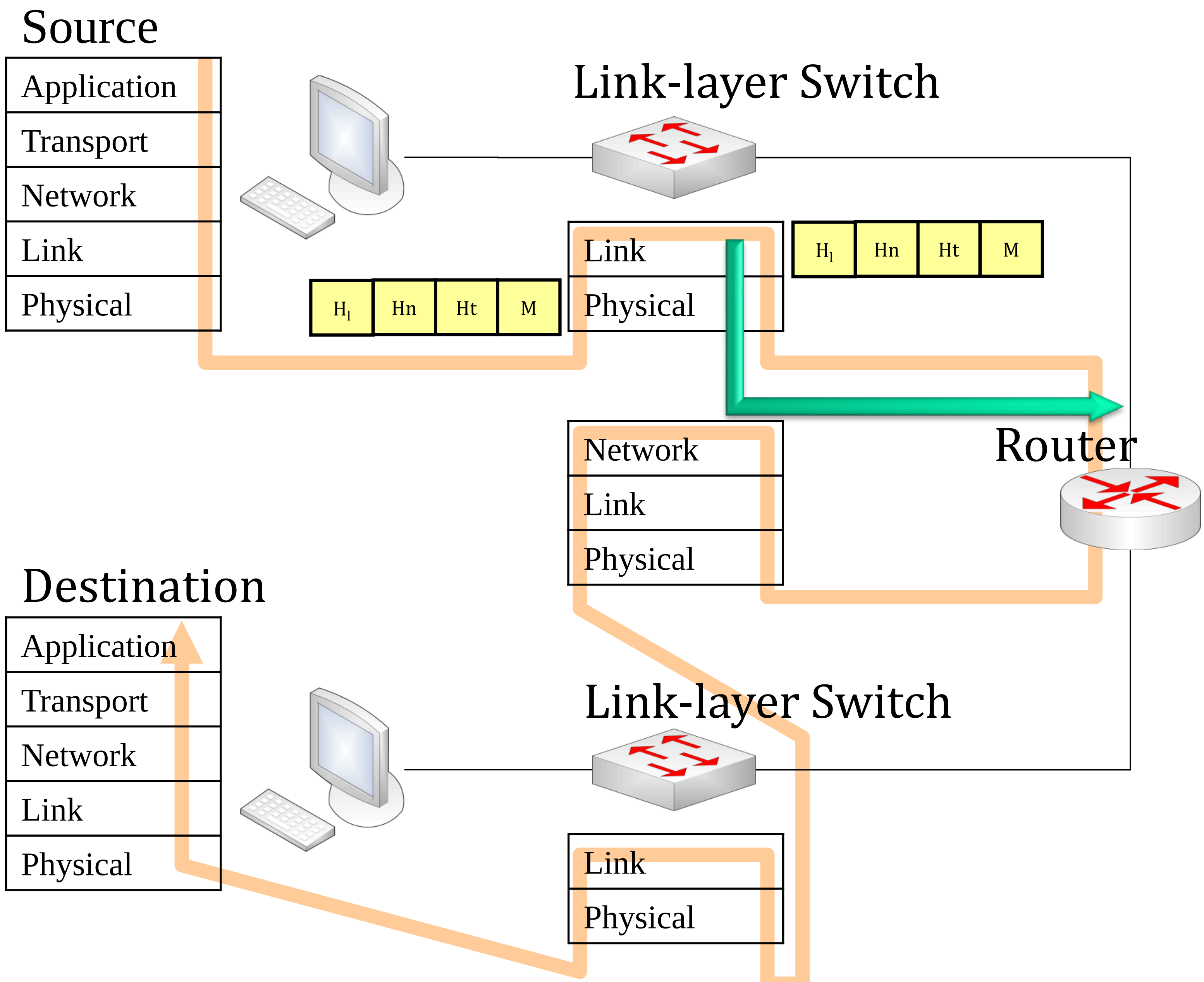
- Each layer has a header
  - A header analogy is an envelope that contains source and destination addresses
- Link layer has a header containing MAC (medium access control) addresses
- Network layer has a header containing IP addresses
- Transport layer has a header containing the port (service) number

Terms for bits processed in each layer

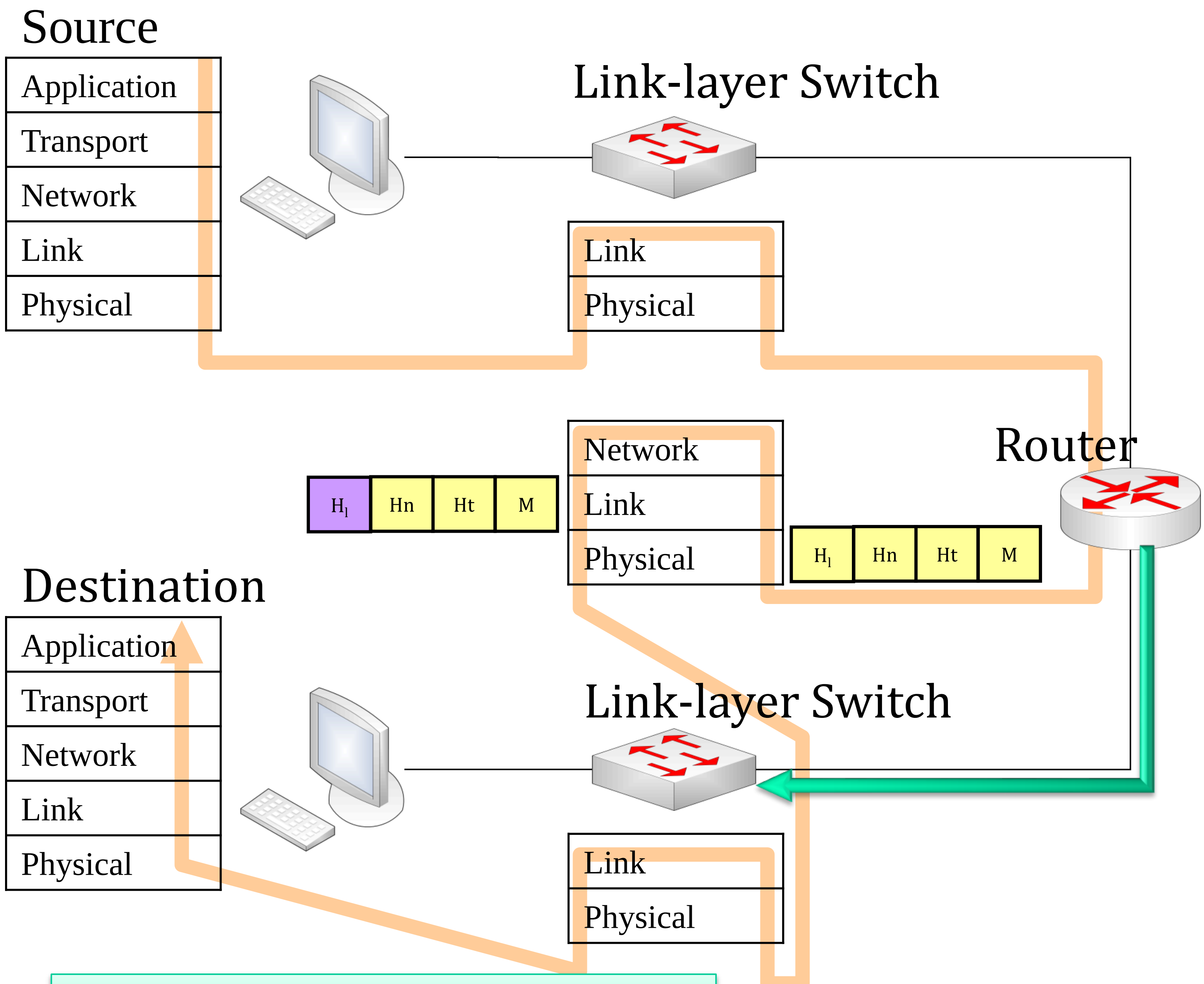




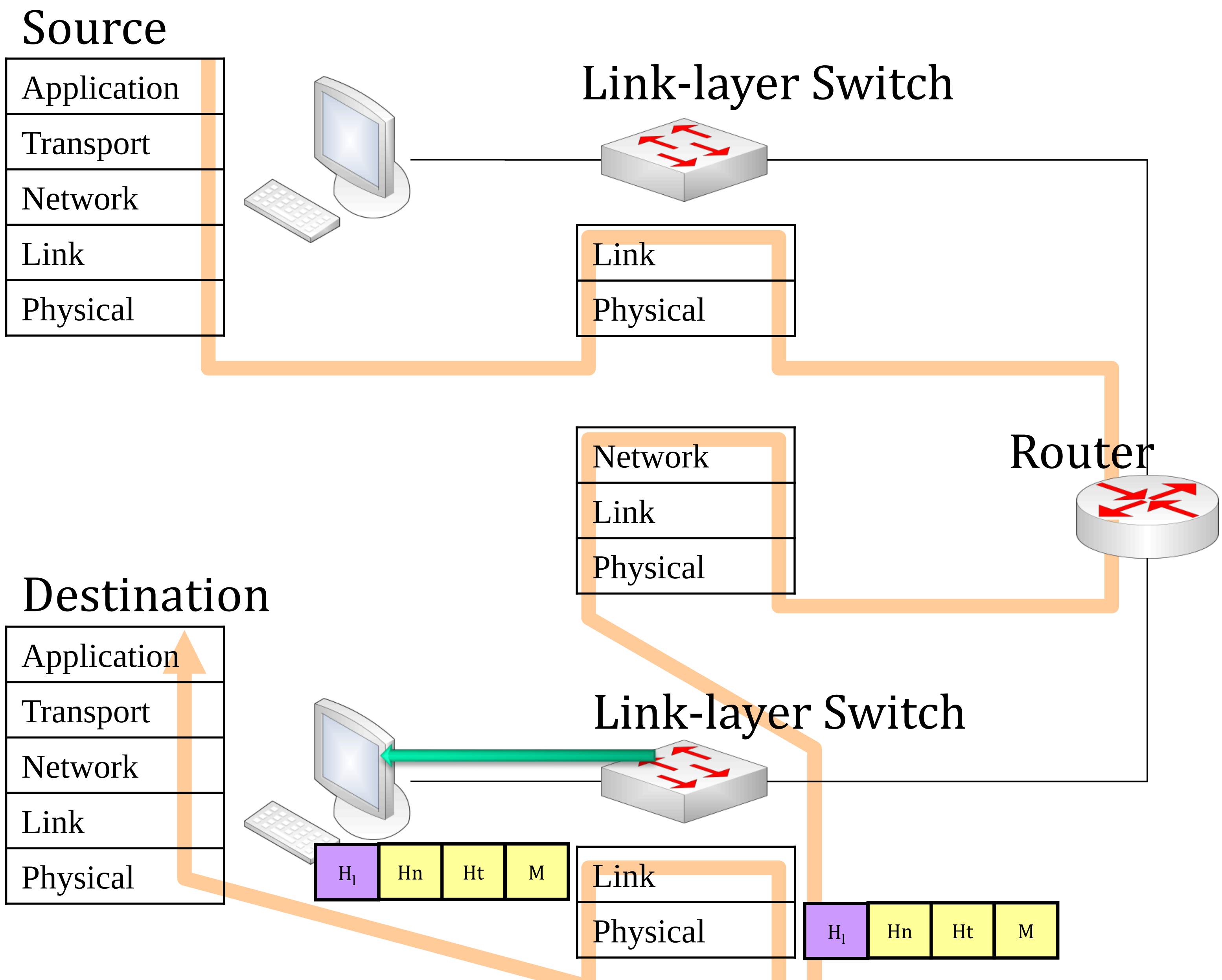
1. Delivery from Source to Switch



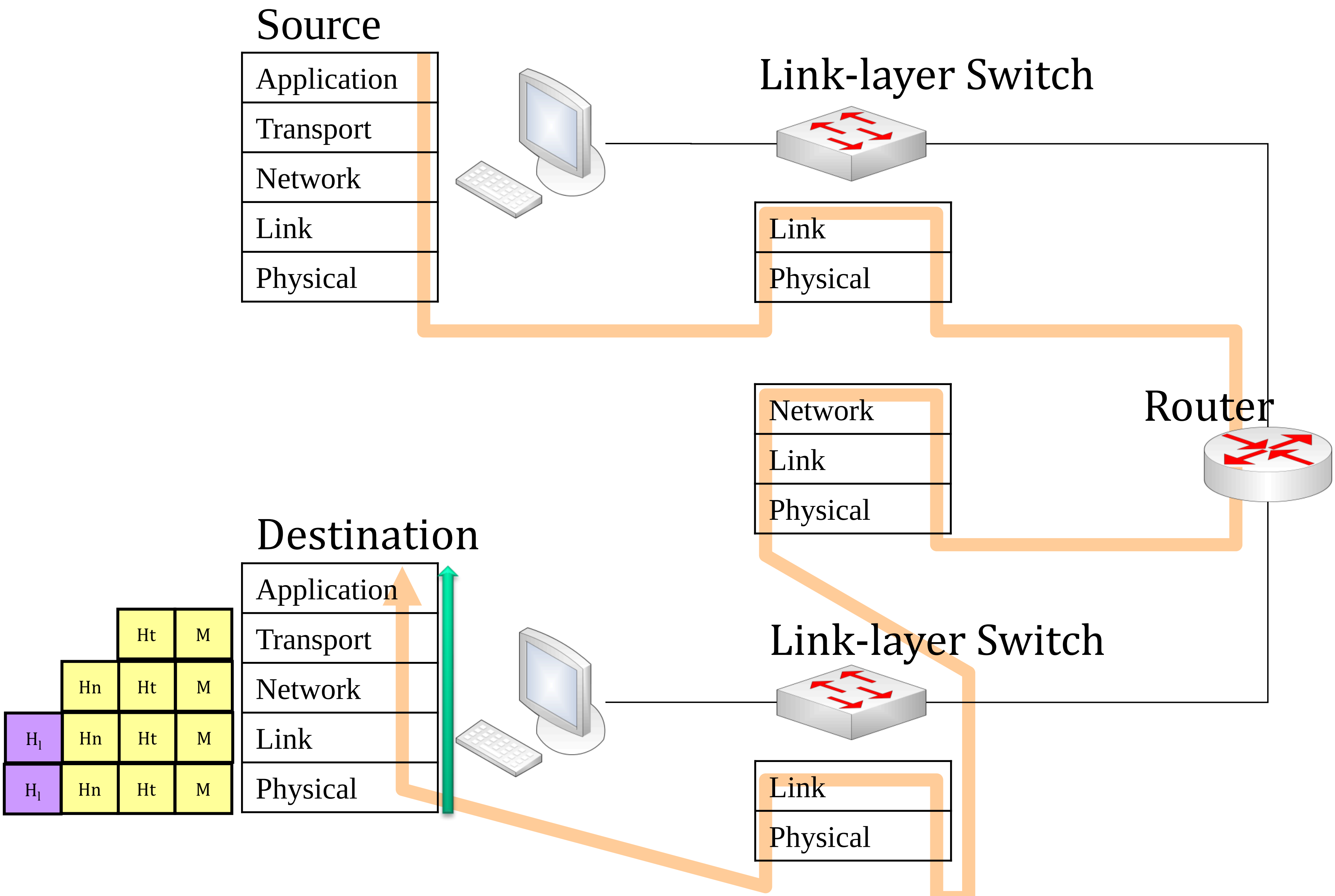
2. Delivery from Switch to Router.



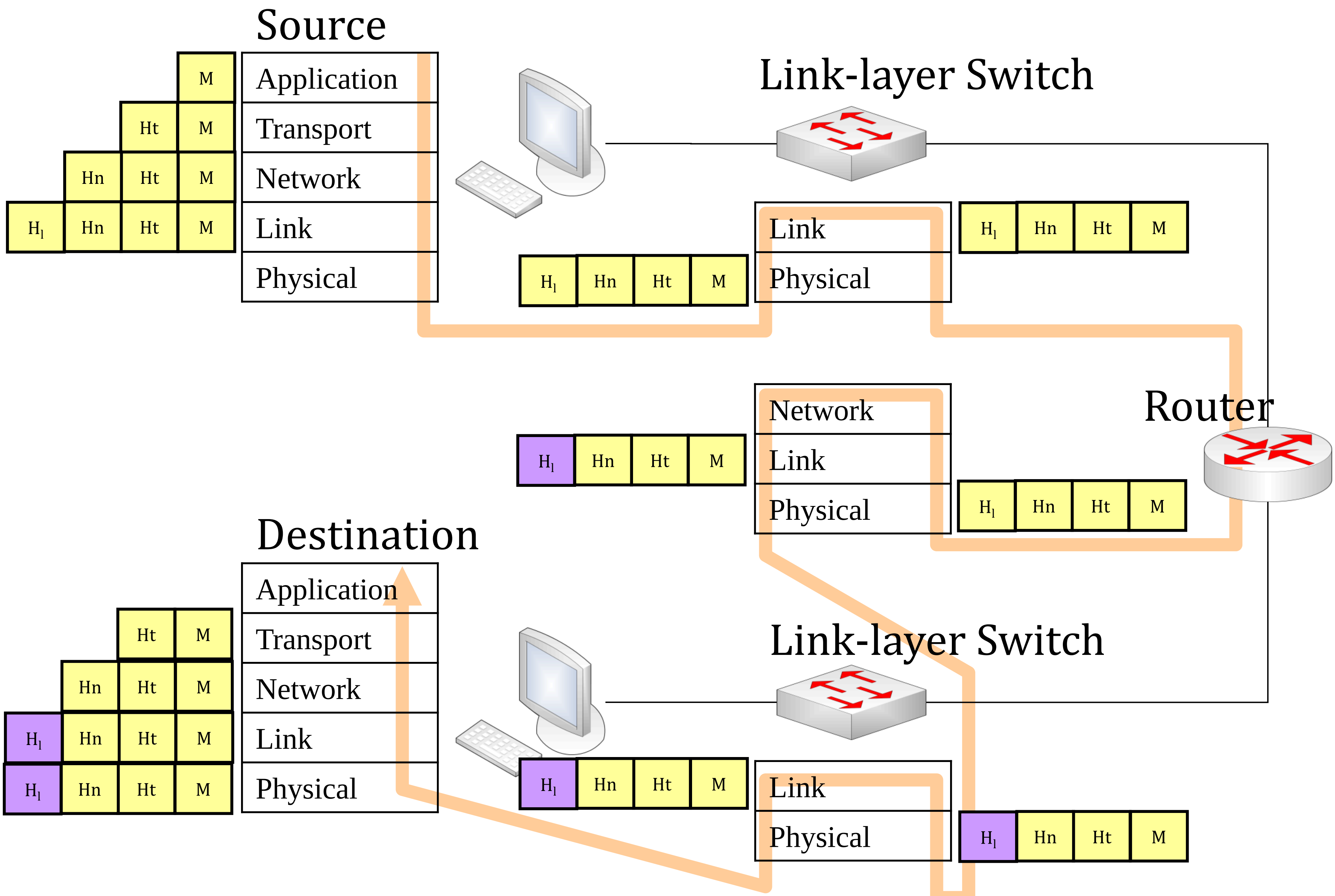
3. Delivery from Router to Switch



4. Delivery from Switch to Destination.



5. Delivery between the Internet Layers.



The entire delivery process.

Router and switch functions (1)

- A Layer 2 (Link-layer) switch cannot change the destination MAC address under any circumstance
- The Layer 2 switch, via a switching table, understands which port is designated by the destination MAC address. So, the switch can process the packet and direct it toward the correct port
  - The switching table is learned from each source's MAC address
- The source computer must know the IP address of the first router (gateway) and uses the address resolution protocol(ARP) to obtain its MAC address
  - The destination MAC address of the packet leaving the source PC is the MAC address of the first router's interface.
  - However, the destination IP address is the destination PC's IP address

Router and switch functions (2)

- Routers and Layer 3 switches understand both IP addresses and MAC addresses
  - Routers work together to generate routing tables
  - A router or layer 3 switch knows the next hop's IP address from the routing table
  - The router then uses the ARP protocol to determine the MAC address of the destination PC (not layer 2 switch)
  - So, the destination MAC address, and the source MAC address, is changed by the router
  - Then the layer 2 switch, between the router and next PC, can switch correctly in accordance with the given MAC address
- The layer 2 switch learns the switching table from the source MAC address and the router learns the routing table from the IP address using the routing algorithm
- Details can be found in Part 3 of the book

Procedure for Internet Use

Initialization

0. Boot up the computer
1. Acquire an IP address through DHCP
2. Determine gateway MAC address by ARP

DHCP: Dynamic Host Configuration Protocol

MAC address of a router interface

Using HTTP

1. Obtain the IP address of the web server via DNS
2. Send the HTTP request through router
3. Route packet to the destination web server
4. Web server sends back HTTP response to the client

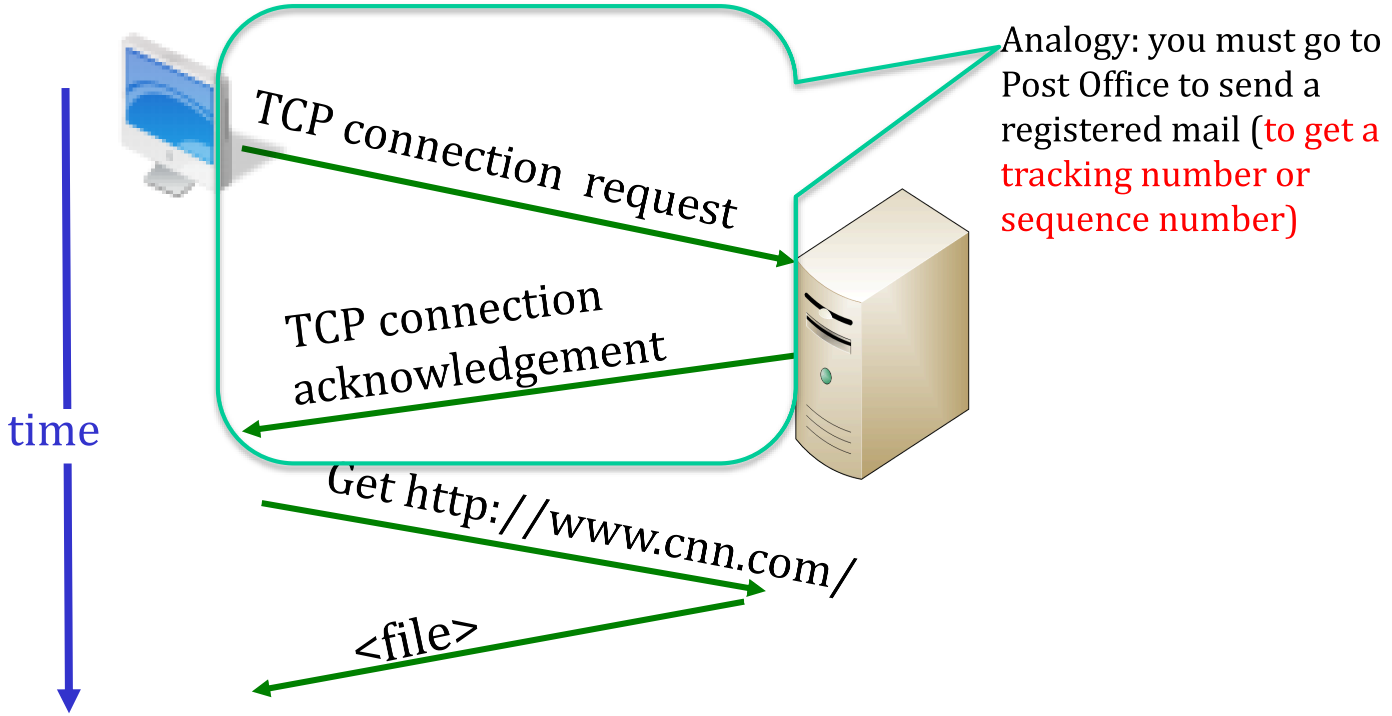
Protocols (1)

- Network protocols
  - All communication and activities in the Internet are governed by protocols
    - E.g. DHCP provides a client with an IP address, gateway IP address and DNS IP address
  - Protocols define
    - Packet format
      - Service (port) number in the TCP header, e.g. port 80 for http
      - Sequence and acknowledgement numbers are in the TCP header
    - The sequence of packets sent and received among network entities
    - Actions taken based on the parameters in the fields of a received packet
      - Retransmit of a packet depends on the acknowledgement number

- Speaking the same language using the same standard set by IETF
- Syntax and semantics are critical

HTTP protocol

- A connection is established between client and server
  - For reliable information delivery (aka connection-oriented service) using a packet sequence number
  - Connection can be established for the socket



Protocols (2)

- Protocols (e.g., Ethernet 802.3, IP, TCP, HTTP) govern the following
  - Sending and receiving information packets according to standards
  - Taking actions specified in packets
  - Managing packet flow and congestion for optimal performance
  - Recovering lost packets
  - Forwarding packets from source host to destination host
- Example
  - Applications (such as HTTP) invoke transport protocols (TCP)
  - Transport protocols invoke the IP protocol
  - IP protocol invokes the Ethernet or equivalent protocol
  - Domain Name System (DNS) is used for naming
  - Glue between protocols (ARP, DHCP, ICMP)

Chapter 0 Outline

Part 0

- Internet architecture
- Access networks
- Network core
- Packet switching and circuit switching
- Packet Switching Delays
- Protocol stack
- Internet history

Internet History (1)

- 1961: queueing theory demonstrates the effectiveness of packet-switching developed by Kleinrock
- 1964: packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational
  - 4 nodes: UCLA, SRI, UCSB and U. of Utah
- 1972:
  - ARPAnet public demonstration
  - NCP (Network Control Protocol) first host-host protocol
  - First e-mail program
  - ARPAnet has 15 nodes

Internet History (2)

- 1970: ALOHAnet satellite network in Hawaii
- 1974: Cerf and Kahn's architecture for interconnecting networks – foundation of Internet protocol
  - Minimalism, autonomy - no internal changes required to interconnect networks
  - Best effort service model
  - Stateless routers
  - Decentralized control
  - Reliable transport
- 1976: Ethernet at Xerox PARC, Intel and Dec
- late70's:
  - Proprietary architectures: DECnet, SNA, XNA
  - Switching fixed length packets (ATM) in hardware for virtual circuit

Internet History (3)

- 1979: ARPAnet has 200 nodes
- 1983: deployment of TCP/IP
- 1982: SMTP e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: FTP protocol defined
- 1988: TCP congestion control
  - New national networks: BITnet, NSFnet
    - NSFnet connects supercomputer centers and users
  - 100,000 hosts connected to confederation of networks
- Early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
  - NAP's (network access points) are established for connecting ISPs

Internet History (4)

- Early 1990s: Web
  - hypertext
  - HTML, HTTP
  - 1994: Mosaic, later Netscape
- Late 1990's – 2000's:
  - Commercialization of the Web
  - Instant messaging and P2P file sharing for music attracted many users
  - Network security to the forefront
  - Estimate 50 million hosts, 100 million+ users
  - Backbone links running at Gbps
  - Field test of Internet
    - Decentralized control
    - 1991 Gulf war: Iraq still placed orders to a company in Atlanta by email

Internet History (5)

- 2009 and beyond:
  - ~6.7 billions of users (August, 2008, source: http://www.internetworldstats.com/stats.htm)
  - The International Telecommunications Union (ITU): two billion users by the end of 2010
    - That is nearly a third of the world's total population (currently estimated at about 6.9 billion)
    - Source: http://www.techspot.com/news/40741-internet-to-exceed-2-billion-users-this-year.html
  - ComScore World Metrix audience measurement service reported that total global Internet audience (age 15 and older from home and work computers) has surpassed 1 billion visitors in December 2008 the first time

Internet History (6)

- China: 18%
- US: 16.1%
- Google family of sites: 777.9 million visitors
- Microsoft: 647.9 million visitors
- Yahoo sites: 562.6 million visitors
- Facebook: 222 million visitors
- Source: http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=9126796&source=NLT_PM

- 2009 and beyond:
  - Voice/Video over IP and unified messaging
  - P2P applications: BitTorrent (file sharing), Skype (VoIP), PPLive (video)
  - Social applications: YouTube, Facebook, Twitter, gaming, web 2.0
  - Wireless and mobility

Global Information Grid (GIG) (1)

- A Communications project of the United States Department of Defense
  - Secure, optical terrestrial network that delivers very high-speed classified and unclassified Internet Protocol (IP) services to 87 key operating sites worldwide in 2005
  - Every site has an OC-192 (10 Gbps) pipe
- Physical manifestation of network-centric warfare (NCW)
  - A robustly networked force improves information sharing
  - Information sharing enhances the quality of information and shared situational awareness
    - Enables collaboration and self-synchronization and dramatically enhances sustainability and speed of command
    - Increase mission effectiveness
  - Source: DoD NCW Report to the Congress

Global Information Grid (GIG) (2)

- 9 functional GIG ES (Enterprise Services) core services in 2004
  - Storage
  - Messaging
  - Enterprise Service Management
  - Discovery
  - Mediation
  - Information Assurance
  - Application Hosting
  - User Assistant
  - Collaboration
- GIG provides authorized users with
  - A seamless, secure, and interconnected information environment
  - Real-time and near real-time response of ES

GIG (3)

- GIG must allow both human users of the GIG, and automated services acting on behalf of GIG users, to access information and services from anywhere, based on need and capability
  - Information must be labeled and also cataloged using metadata
    - Allowing users to search and retrieve the information required to fulfill their mission under a "smart-pull"
  - This requires the GIG to know where the information is posted and to recognize who the user is, regardless of location
- Access to information will be restricted based on the threat inherent to that location
  - Enforce user privileges and access to the information
  - Provide mechanisms that ensure the information is coming from its claimed source
  - Security is an embedded feature
  - Deny an adversary's ability to access the information

Introduction: Key concepts

- Internet architecture: network edge, network core, and access network
- Internet protocol layers and models
- Packet-switching-versus-circuit-switching
- Packet loss, delay, congestion and throughput
- Layer 2 switch, layer 3 switch and router functions
- History