National University of Computer & Emerging Sciences

CS 3001 – COMPUTER NETWORKS

Lecture 03

Chapter 1

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Nauman Moazzam Hayat

nauman.moazzam@lhr.nu.edu.pk

Office Hours: 01:00 pm till 06:00 pm (Every Tuesday & Thursday)

Network Edge (Client, Server, Peer)

Network edge comprises of the millions and billions of end systems / hosts and applications which reside in them

An end system (or host) can either request service (***client***) or provide service (***server***) or act as both interchangeably (***peer***).

Server

- A server is a service provider providing access to network resources:
  - A server can have multiple roles (e.g web servers, mail servers, print servers, Remote Access Servers (RAS), Directory Servers (DNS) etc)
  - Always on host
  - Permanent IP address
  - Most servers reside in large data centres

Client

- A client is a requestor of these services
  - May be intermittently on
  - may have dynamic IP address
  - do not communicate directly with each other

Peer

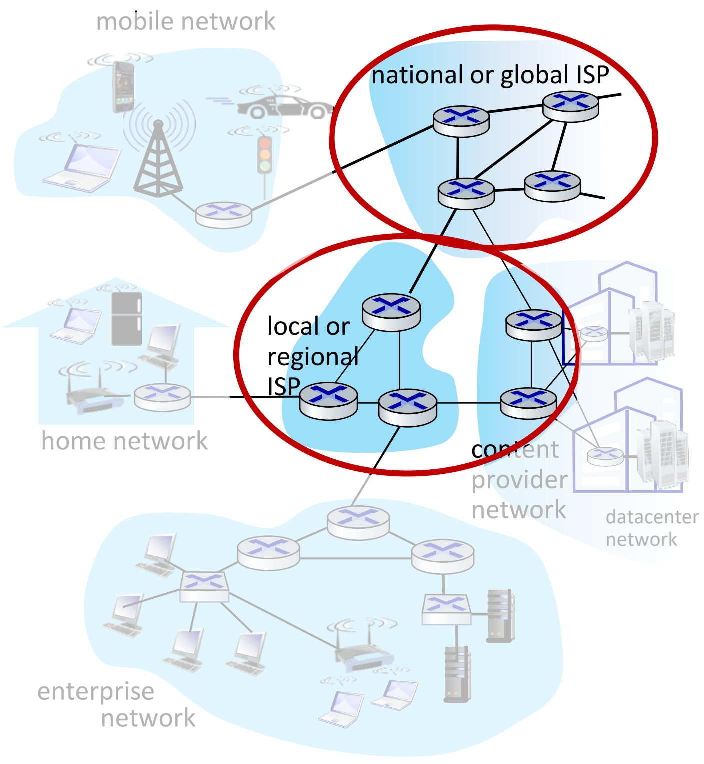
- A Peer-to-Peer network doesn't have dedicated servers. All hosts are equal and they both provide and request service i.e. they have both client & server functionalities.
  - Not always on server
  - arbitrary end systems directly communicate
  - peers are intermittently connected and change IP addresses
  - complex management
  - Examples are Skype, BitTorrent, Napster

Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
- Network edge: hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

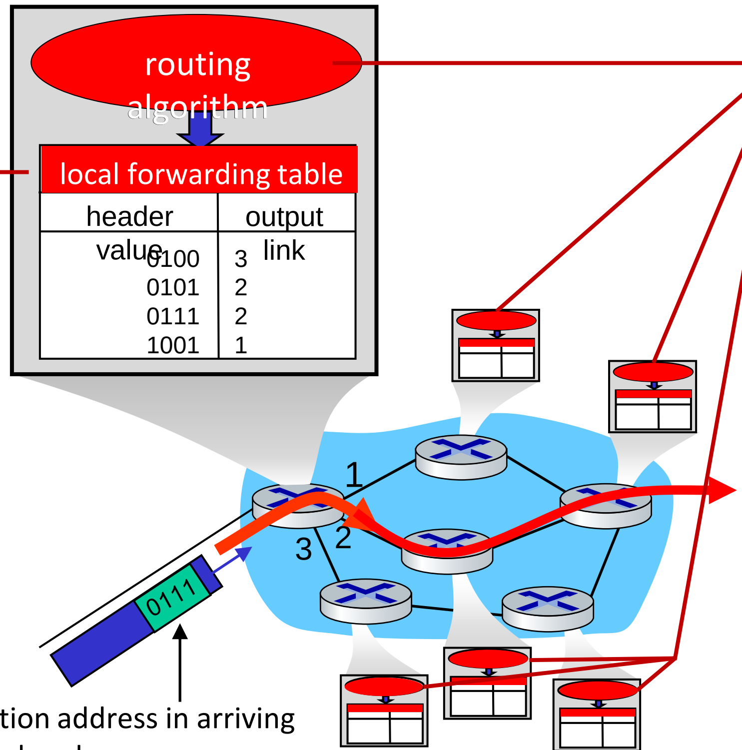
The network core

- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - network forwards packets from one router to the next, across links on path from source to destination



Two key network-core functions

Forwarding:
- aka "switching"
- *local* action: move arriving packets from router's input link to appropriate router output link



Routing:
- *global* action: determine source-destination paths taken by packets
- routing algorithms


routing
45 h
3,053 miles
48 h
3,309 miles
San Jose
Northampton
United States
Seattle
Portland
Sacramento
San Francisco
Las Vegas
Los Angeles
San Diego
Phoenix
Tucson
El Paso
Dallas
Austin
Houston
San Antonio
New Orleans
Kansas City
Minneapolis
Chicago
Detroit
Toronto
Ottawa
Montreal
Quebec City
Indianapolis
Nashville
Atlanta
Charlotte
Jacksonville
Orlando
Tampa
New York
Philadelphia
Victoria
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEVADA
UTAH
COLORADO
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
TENNESSEE
KENTUCKY
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
FLORIDA
MARYLAND
DE
NJ
CT
RI
VERMONT
MAINE
BAJA CALIFORNIA
SONORA
CHIHUAHUA
COAHUILA


forwarding
forwarding
45 h
3,053 miles
48 h
3,309 miles
United States
Victoria
Seattle
WASHINGTON
Portland
San Francisco
San Jose
CALIFORNIA
Las Vegas
Los Angeles
San Diego
ARIZONA
Phoenix
Tucson
El Paso
NEW MEXICO
COLORADO
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
Minneapolis
WISCONSIN
IOWA
KANSAS
Kansas City
MISSOURI
OKLAHOMA
TEXAS
Dallas
Austin
Houston
San Antonio
ARKANSAS
LOUISIANA
New Orleans
MISSISSIPPI
ALABAMA
Atlanta
TENNESSEE
Nashville
KENTUCKY
ILLINOIS
INDIANA
Indianapolis
Chicago
MICHIGAN
Detroit
OHIO
Toronto
Ottawa
Montreal
Quebec City
MAINE
VERMONT
NEW HAMPSHIRE
Northampton
New York
RI
CT
Tampa
FLORIDA
BAJA CALIFORNIA
SONORA
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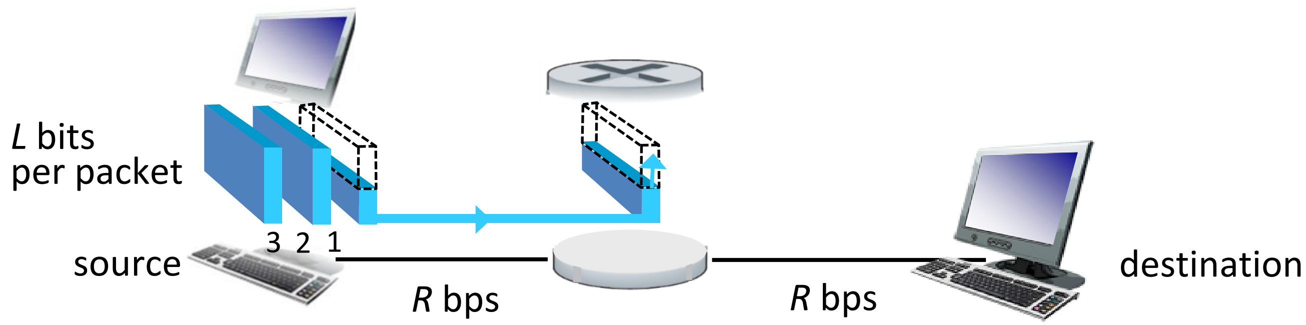
Sacramento
Cleveland
DOWNTOWN
CENTRAL
OHIO CITY

Packet-switching: store-and-forward

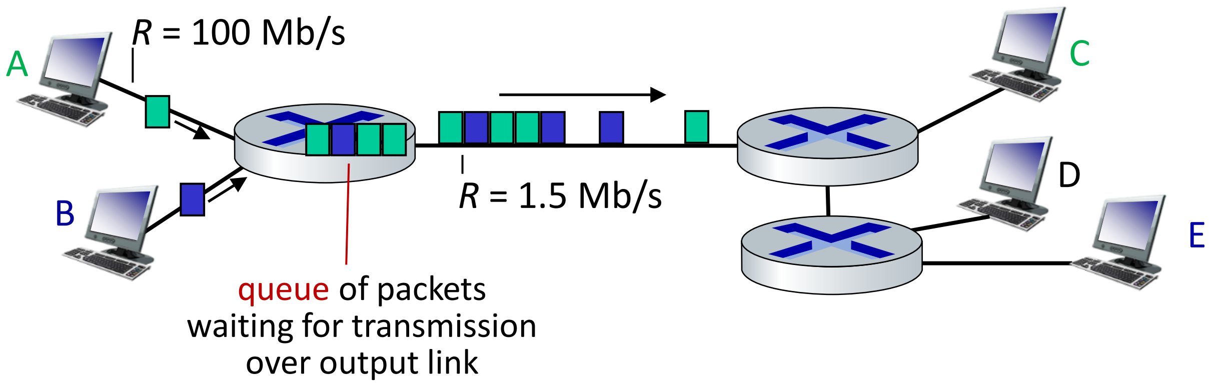


- packet transmission delay: takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *store and forward: entire* packet must arrive at router before it can be transmitted on next link

One-hop numerical example:

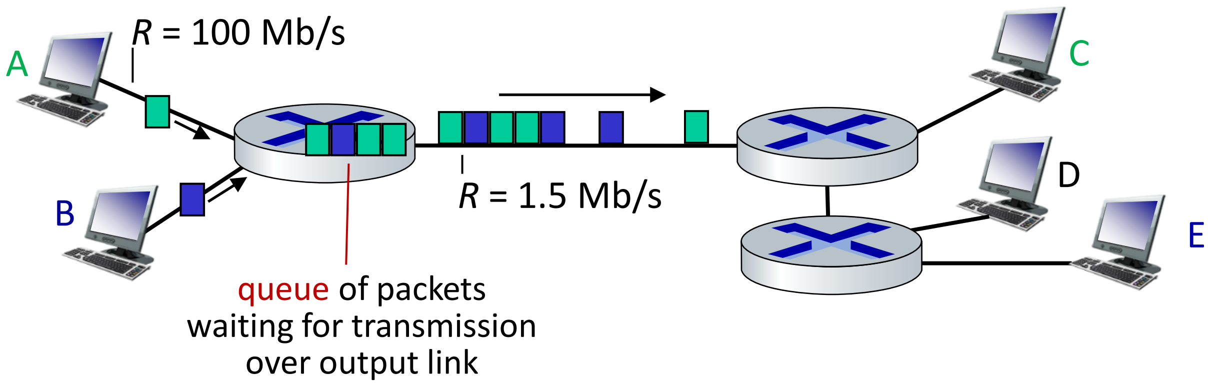
- L = 10 Kbits
- R = 100 Mbps
- one-hop transmission delay = 0.1 msec

Packet-switching: queueing



Queueing occurs when work arrives faster than it can be serviced:

Packet-switching: queueing



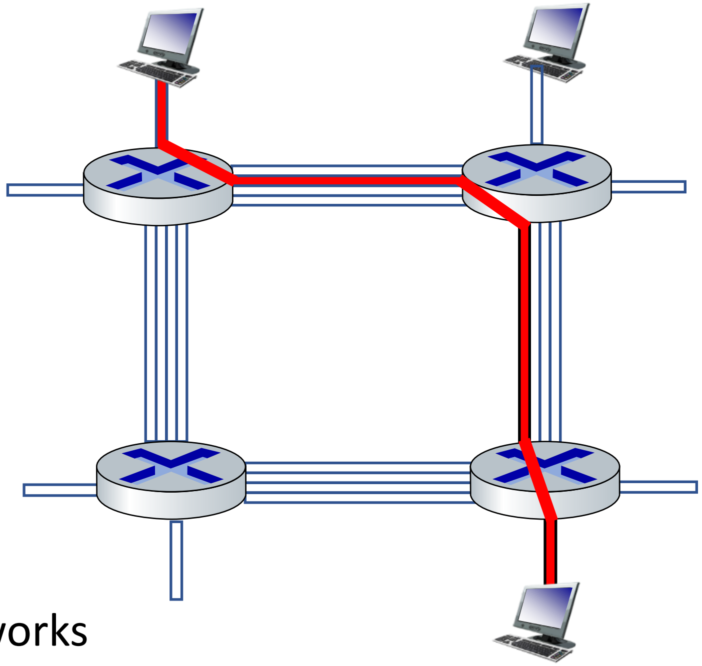
Packet queuing and loss: if arrival rate (in bps) to link exceeds transmission rate (bps) of link for some period of time:

- packets will queue, waiting to be transmitted on output link
- packets can be dropped (lost) if memory (buffer) in router fills up

Alternative to packet switching: circuit switching

end-end resources allocated to, reserved for "call" between source and destination

- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call (no sharing)
- commonly used in traditional telephone networks

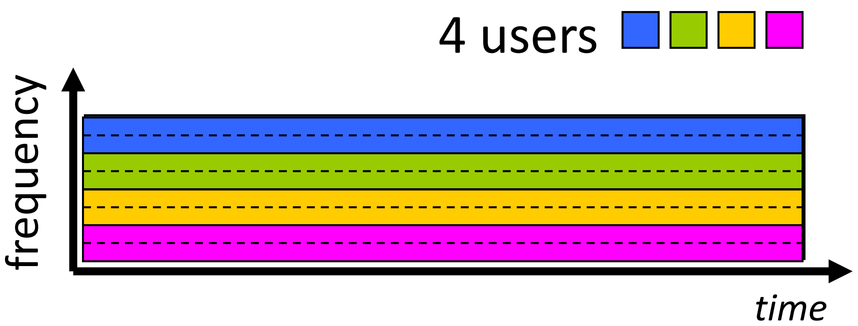


* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive

Circuit switching: FDM and TDM

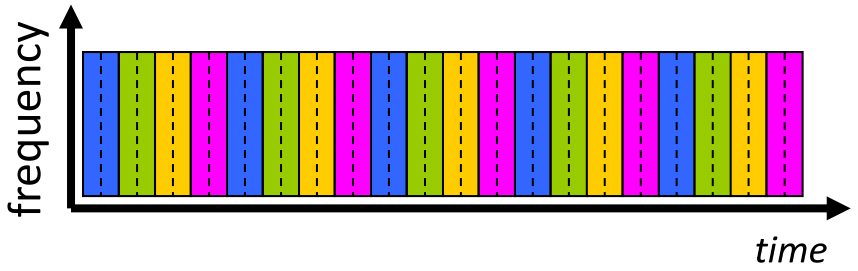
Frequency Division Multiplexing (FDM)

- optical, electromagnetic frequencies divided into (narrow) frequency bands
- each call allocated its own band, can transmit at max rate of that narrow band



Time Division Multiplexing (TDM)

- time divided into slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band (only) during its time slot(s)



Numerical Example

- How long does it take to send a file of 80 Kbytes from host A to host B over a circuit-switched network?

- All links are 1.536 Mbps
- Each link uses TDM with 24 slots/sec
- Time to establish end-to-end circuit is 500 msec

Let's work it out!

Numerical Example: Solution

- 80 Kbytes is 640,000 bits

– NOTE: networks in bits, end systems in bytes
– NOTE: 8 bits to a byte

- Each circuit has a rate of 1.536Mbps / 24
  => 1536000/24 = 64000bps

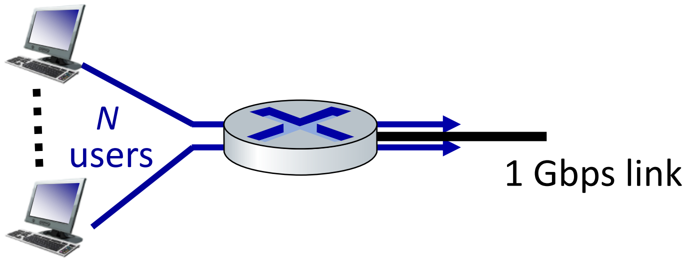
- So, it takes 640000 bits / 64000 bps = 10 seconds to transmit the file

- Need to add the circuit establishment time ($\frac{1}{2}$ second)
- So, 10.5 seconds

Packet switching versus circuit switching

example:

- 1 Gb/s link
- each user:
  - 100 Mb/s when “active”
  - active 10% of time



Q: how many users can use this network under circuit-switching and packet switching?

- *circuit-switching:* 10 users
- *packet switching:* with 35 users, probability > 10 active at same time is less than .0004 *

Q: how did we get value 0.0004?

A: HW problem (for those with course in probability only)

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive

Packet switching versus circuit switching

Is packet switching a "slam dunk winner"?

- great for "bursty" data – sometimes has data to send, but at other times not
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: packet delay and loss due to buffer overflow
  - protocols needed for reliable data transfer, congestion control
- *Q:* How to provide circuit-like behavior with packet-switching?
  - "It's complicated." We'll study various techniques that try to make packet switching as "circuit-like" as possible.

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet switching)?